# Increasing Crop Production through Improved Plant Protection

## Volume II

Edited by
Abraham Tadesse

Plant Protection Society of Ethiopia (PPSE)

Sponsors:
EIAR, Netherlands Ministry of Agriculture, Nature and Food Quality, FAO and MoARD

agriculture, nature and food quality

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# The Plant Protection Society of Ethiopia

The Plant Protection Society of Ethiopia (PPSE) is a non-profit professional association established in 1992 by the merger of two previously formed committees: the Ethiopian Phytopathological Committee (EPC), established in 1976, and the Committee of Ethiopian Entomologists (CEE), established in 1981. The objective of PPSE is to contribute towards the development of Ethiopian agriculture by reducing crop losses caused by pests through promoting effective research, documenting and dissemination of scientific information, encouraging professional growth and fostering interdisciplinary interaction among plant protection scientists to solve problems related to plant protection.

PPSE has organized 16 annual conferences since its establishment. The 14th annual conference was special of its kind because of two reasons: firstly, two decades of plant protection research in the country was reviewed, and secondly, it was conducted during the celebration of the society's 15th Anniversary.

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# Part IV: General Plant Protection

# Acknowledgements

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The publication of this volume was financed by the EIAR, the Netherlands Ministry of Agriculture, Nature and Food Quality; the Food and Agriculture Organization of the United Nations (FAO) and MoARD especially the Animal and Plant Health Regulatory Directorate (APHRD) for which we are very grateful.

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A special word of thanks should go to His Excellency Dr. Abera Deressa, State Minister, Ministry of Agriculture and Rural Development, not only for his interest and encouragement during preparation for the conference but also for his kind assistance in securing funds from the USAID-Ethiopia and the BTC.

We would like to express our gratitude to Dr. Solomon Assefa, DG of EIAR, for his moral, material, and financial support to PPSE.

We wish to thank the conference organizing committee members, representing different institutions and disciplines: Dr. Amsal Ayana (Crops Research Director, ORARI), Dr. Eshetu Bekele (EIAR, Holetta), Dr. Ferdu Azerefegne (Hawassa University), Dr. Fasil Reda (EIAR, Melkassa), Dr. Seid Ahmed (Crops Reseach Director, EIAR), Mr. Wondirad Mandefro (Ambo, PPRC), Mrs. Tsehay Azage (APHRD, MoARD) and Dr. Taye Tessema (PPRC, Ambo) for their valuable contributions at the initial stage of planning and organizing the conference.

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We would like to thank Mr. Solomon Abate who kindly did the tedious task of formatting all papers in this volume. Mr. Abebe Kirub assisted in designing and page layout, in addition to his technical advice during the publication of this book.

Our sincere thanks go to the group of panelists namely Dr. Seme Debella (moderator), Dr. Brhane G/ Kidan, Dr. Dereje Ashagari, Dr. Tessema Megenassa, Dr. Chemeda Fininsa, and Mr. Rezene Fessahaie. Dr. Ferdu Azerefegne and Dr. Seid Ahmed served the session as rapporteurs.

Finally, I would like to give the greatest glory to the almighty God who gave us the strength and patience to publish all of the papers that were presented in the conference. If it were not by the grace of God, the publication of many of the papers in both volumes would have not been possible.

*Abraham Tadesse (PhD)*
*President, PPSE*

# Foreword

Although agriculture is the backbone of the Ethiopian economy, agricultural production and productivity remained very low, even by African standard. Several factors contribute to the poor performance of the Ethiopian agriculture; low level of access to improved crop production and protection technologies is among the most important constraints.

In the past two decades, a wide range of research activities have been carried out at the EIAR and other research and higher learning institutions in order to find solutions to the problems. Plant protection technologies such as chemical, varietal, biological and physical methods of pest control have been developed, and a wealth of research information has been accumulated, prompting this effort to review and publish in a form readily available to users.

I greatly appreciate the efforts made by the Plant Protection Society of Ethiopia to have taken the initiative to organize the review conference and made the publication of the outcomes of the conference possible.

In our effort to attain food security, there is no doubt that the application of plant protection technologies is the key factor without which, when put into practice, success becomes remote. It is in this context that the information presented in this publication will prove helpful in minimizing the extent of losses due to pests, and in identifying the gaps for future research thrusts. Moreover, the book contains list of pests associated with different crops that could be used as a basis for the development of a national pest list required for phytosanitary purposes. I believe that this book will serve as a valuable source of information for planners, researchers, producers, teachers and others interested in plant protection in Ethiopia.

I would like to express my heartfelt appreciation to those organizations, groups and individuals for making their contributions to the success of the conference and the publication.

*Solomon Assefa (PhD)*
*Director General, EIAR*

# Preface

Concerted research on plant protection was launched with the establishment of the Institute of Agricultural Research (IAR) in 1966. Research carried out at various IAR centers and other institutions had been reviewed in the First Ethiopian Crop Protection Symposium organized by the Crop Protection Department of IAR in 1985. Results were published. Research results obtained ever since have been scattered over different publications and in unpublished forms denying easy access to users. It was, therefore, felt necessary to arrange a forum whereby plant protection research conducted since 1985 could be reviewed and documented. The Plant Protection Society of Ethiopia (PPSE) took the initiative to gear its 14th Annual Conference towards achieving this goal. The Conference was jointly organized by PPSE and EIAR. This publication is the outcome of the Conference under the theme *Two Decades of Plant Protection Research in Ethiopia and Prospects for the New Millennium* held at EIAR, Addis Ababa, Ethiopia, 19-22 December 2006. Thirty seven review papers (11 on entomology, 10 on pathology, 10 on weeds, six on general plant protection and 1 on policy and regulatory aspects of plant protection) were presented and discussed in the four-day conference.

The publication is divided into two volumes under the title “increasing crop production through improved plant protection”. The first volume of the book consists of results of research on pests of cereals and grain legumes, post-harvest pests, seed health and plant quarantine.

This volume contains four parts. Part I is entomology, part II is pathology, part III is weeds, and part IV is general plant protection. The crops covered are root and tuber crops, vegetable crops, fruit crops, oil crops, coffee, fiber crops, sugarcane, flowers, aromatic, medicinal and non-edible oil bearing plants, and forest trees. In addition to insect, disease and weed pests, this volume comprises of research information on migratory insect and vertebrate pests and on prevention of accumulation of obsolete pesticides.

As editor of both volumes, I have realized that there are clear differences in the amount of information available on different crops and in different disciplines. Some crops and disciplines have adequate information. Others such as weeds in fruit crops appeared to have been neglected meriting more serious research attention in the future.

As the principal objective is to review the results generated by the various disciplines and to collate a comprehensive bibliography of local publications

on plant protection research, contributors were encouraged to include as much data as possible in tabular forms and to be exhaustive in their bibliographic lists.

I acknowlege the delay in the publication of this document for various reasons. However, the delay enabled us to publish all of the papers presented in the review conference some of which were recieved as late as May 2009, three and half years after the conference.

At this juncture, I would also like to apologize for the editorial errors in both volumes of the book. The editorial work was done under severe time presure; donors wanted us to observe the publication deadline. Especially volume I was done at a time when I was fully engaed in the busines process reengineering of my institute (the EIAR), the time when I almost ceased any other activity for more than one year. Also some of the papers in volume one were recieved almost a day before the document went to printing.

Despite any shortcomings, it is hoped that this book will prove useful to plant protection students and teachers, researchers and extension workers, and others dealing with plant protection and ultimately the farming community.

In view of the multidisciplinary and interdependent nature of plant protection, we sought the cooperation of scientists from numerous organizations in carrying out the peer review of the papers. Although the names of the scientists appear in the acknowledgements, we would like to record our gratitude here for their participation in this demanding task.

We hope that this volume would be better for all the efforts expended on it by authors, reviewers and editors. Any imperfections that remain, however, are the responsibility of the authors.

*Abraham Tadesse (PhD)*
*President, PPSE*

# Review of Entomological Research on Root and Tuber Crops in Ethiopia

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## Introduction

Root and tuber crops are very important in Ethiopia supporting large number of the population. The most important root and tuber crops include enset (*Ensete ventricosum*), potato (*Solanum tuberosum*), sweet potato (*Ipomoea batatas*), taro (*Colocassia esculenta*), yam (*Dioscorea* spp.), Ethiopian dinich (*Coleus* spp.), anchote (C*occinia abyssinica*), cassava (*Manihot esculenta*). Insect pests are considered as an important factor contributing to the low amount of yield and deterioration of products in the store. Within the last 20 years, the focus of entomological research has been mainly on potato, sweet potato and slightly on enset. Relatively more research results were obtained on sweet potato butterfly, sweet potato weevil, root mealybug and potato tuber moth.

Potato is one of the very important food and cash crops in Ethiopia, especially in the high and mid-altitude areas. Potato was introduced to Ethiopia first by Schimper, a German botanist, in 1858 (Horton, 1987 and Pankhurst, 1964 cited by Gebremedhin *et al*., 2006). The national average yield did not change much, about 9 t/ha, which is much lower than the world average, 15 tons/ha (FAO, 2001). Since mid 1970s, the land under potato production has been increasing and reached more than 160,000 ha (Gebremedhin *et al*., 2006). The production is both under rain-fed and small-scale irrigation. The most important factors responsible for the low productivity of potato are the low yielder potato cultivars currently under use and susceptibility to the major disease and insect pests. During the last two decades, the status of potato insect pests did not change from what was reported by Bayeh and Tadesse in 1992.

Sweet potato is one of the most important root crops supporting a considerable portion of the population as a source of food and feed in Ethiopia. It has been

cultivated as food crop for several years and over 95% of the crop produced in the country is grown in the South, South-western and Eastern parts, where it has remained for centuries as an important co-staple for the community (Terefe, 1987). In the Southern Nations, Nationalities and Peoples Region (SNNPR) of Ethiopia sweet potato is the second most important root crop next to enset in area coverage and production (Assefa *et al.,* 2004 unpublished). In 1993/94, it occupied 49,000 ha with a total production of 343,573 tons. In 1999, the total area of sweet potato in SNNPR reached 52,021.71 ha with a total production of 379,758.48 tons (CSA, 1994; 1999). The national average yield of sweet potato was 7 t/ha in 1999 and increased to 7.3 t/ha in 2006/2007. The yield of sweet potato could increase dramatically to 30-50 t/ha by using improved varieties and the available technologies (Assefa *et al*., 2004 unpublished). There are a number of biophysical and socio-economical constraints that have been hindering the increase in the productivity of sweet potato under farmers' circumstances. Lack of high yielding varieties and pest damage has been cited as the most important limiting factors.

Enset-based farming systems play an important role in food security of Ethiopia. The human carrying capacity of enset and enset based farming system is high and is likely to be greater than any other crop and cropping systems for the same agro ecology and inputs (Almaz, 2001). According to CSA (1997), the total area covered with enset is 224,400 ha. About 15 million (20%) of the Ethiopian population depends on enset as staple and co-staple food source. Enset grows in a wide range of altitudes. It grows below 500 masl (Omo Ratae) under irrigation and at 3200 masl as rain-fed crop. It grows luxuriously in elevations between 2000 and 2750 masl under rain fed conditions (Huffnagil, 1961 and Westphal, 1975). There is no national data on the current level of enset production.

# Research findings

## Potato

### Insect pests recorded

For the last two decades, the major insect pests of potato did not differ and include: cutworms (*Agrotis* spp. and *Exigua* spp.), red ants (*Dorylus* sp.), potato epilachna (*Epilachna hirta),* metallic leaf beetle (*Lagria vilosa*), potato aphid (*Macrosiphum euphorbiae*), green peach aphid (*Myzus persicae)* and the potato tuber moth (*Phthorimaea operculella*) (Bayeh and Tadesse, 1992). Among these insects, the potato tuber moth (PTM) received more attention than all the other potato insect pests combined. Lately, the red ants and aphids have received some attention. Hence, the review focuses on PTM, red ants and aphids.

Table 1. Insect pests recorded on Irish potato in Ethiopia.

| Scientific name | Common name | Status | References |
|---|---|---|---|
| **Heteroptera** | | | |
| **Pentatomidae** | | | |
| *Eurydem ornate* (L.) | Cabbage bug | Unknown | 31, 65 |
| **HomOptera** | | | |
| **Aleyrodidae** | | | |
| *Bemisia tabaci* (Gennadius) | Tobacco whitefly | Minor | 31, 65 |
| **Aphididae** | | | |
| *Aphis gossypii* Glover | Cotton aphid | Minor | 31, 65 |
| *Aulacorthum solani* (Kaltenbach) | Potato aphid | Minor | |
| *Macrosiphum euphorobiae* (Thomas) | Pepper aphid | Minor | 31, 65 |
| *Myzus persicae* (Sulzer) | Peach aphid | Minor | 31, 65 |
| **Thysanoptera** | | | |
| **Thripidae** | | | |
| *Aelothrips* sp.? *linaricus* Priesner | Silver banded thrips | Unknown | 65 |
| **Lepidoptera** | | | |
| **Gelechiidae** | | | |
| *Phthorimaea operculella* (Zeller) | Potato tuber moth | Major | 9,23,24,25,31, 44,46,56, 65 |
| **Pyralidae** | | | |
| *Lecucinodes orbonalis* Guenee | Egg plant fruit borer | Unknown | 65 |
| **Noctuidae** | | | |
| *Agrotis segetum* (Schiff.) | Southern cut worm | Minor | 31, 65 |
| *Diachrysia orichalcea (*Fabricius*)* | Golden plusia | Minor | 65 |
| **Sphingidae** | | | |
| *Acheronita atropos (*Linnaeus*)* | Death's hawk moth | Minor | 31, 65 |
| **Hymenoptera** | | | |
| **Tenthredinidae** | | | |
| *Athalia* spp. | Sawfly | Unknown | 65 |
| *Formicidae* | | | |
| *Dorylus* sp. nr *brevinodosus* Mayr | Gojam red ant | Minor | 9, 31, 44, 65 |
| **Coleoptera** | | | |
| **Apionidae** | | | |
| *Apion* spp. | Black pod weevil | Unknown | 65 |
| **Coccinellidae** | | | |
| *Chnootriba simlis* (Thnb.) | Tef epilachna | Unknown | 31, 65 |
| *Epilachna fulvosignata* | Egg plant epilachna | Minor | 31, 65 |
| *Epilachna hirta* (Thunberg) | Potato epilachna | Minor | 31, 65 |
| *Henosepilachna elaterii* (Rossi) | Spotted melon beetle | Unknown | 31, 65 |
| **Tenebrionidae** | | | |
| *Gonocephalum simplex* (Fabricius) | Dusty brown beetle | Minor | 31, 65 |
| **Lagriidae** | | | |
| *Lagria villosa* Fabricius | Metallic beetle | Minor | 31, 65 |
| **Meloidae** | | | |
| *Mylabris flavoguttata* Reiche | Pollen beetle | Unknown | 31, 65 |

# Potato tuber moth (*Phthorimaea operculella*)

## Basic studies

The potato tuber moth originated in the eastern Andes (S. America) where its main solanaceous hosts, potato and tobacco, are thought to have originated (Finney *et al*., 1947; Rothschild, 1986). It is distributed throughout the world following the spread of potato and is presently regarded as a major pest of potato in almost all tropical and subtropical regions (Finney *et al*., 1947). In Ethiopia, it has established itself as an important pest in major potato growing areas. The importance of the pest is expected to increase because of the long distance movement of seed tubers to many places across the country from limited source locations mainly in the cool highlands of North and West Shoa.

The activities of male-adults of PTM were monitored using sex pheromone baited traps at Holetta both in seed tuber stores and in production fields (Bayeh and Tadesse, 1992). The field results showed that PTM activity peaked up during January to February and in June. The two peaks in January and June were mainly attributed to the population that had been multiplying on left over tubers in fields from the main season and irrigated potato harvests, respectively. The catches in February were more important because the off-season planted potato was young in the field and liable for PTM attack. On the other hand, the populations of PTM in the seed tuber stores never showed obvious peaks whereby the number of adults caught remained low all year round. In contrast to this observation, higher population of PTM was recorded in the seed tubers from irrigated fields which stayed longer in the field in one of the monitoring years. These observations showed that prompt harvesting plays significant role in reducing the population of PTM. The usual high population in fields had not been contributing much for infestations that occurred in seed tuber stores. One possible reason for this might be the proper timing of vine killing, which might contribute for the reduction in the movement of more larvae into the soil to infest developing tubers (Bayeh and Tadesse, 1992). Similar studies of monitoring the activity of the male PTM were conducted in the major potato growing areas of the West Amhara from 1998 to 2000 during the potato-growing seasons. Data were recorded at a weekly interval. In Tilili, PTM was present throughout the year because of the practice of growing potato three times per year. Whereas at Adet the diffused light store present nearby to the seed multiplication farms was suspected to have contributed for year round activity of PTM in the field. At Adet, the peak period was between June and October in 1998, July to August in 1999 and only in September in 2000. In Tilili the population peaked from July to September in 1998, July to October in 1999 and after August in 2000. In another study at Melkassa Research Center, the field activity of male PTM adults showed an increase towards the end of the crop maturity period (Fig. 1).

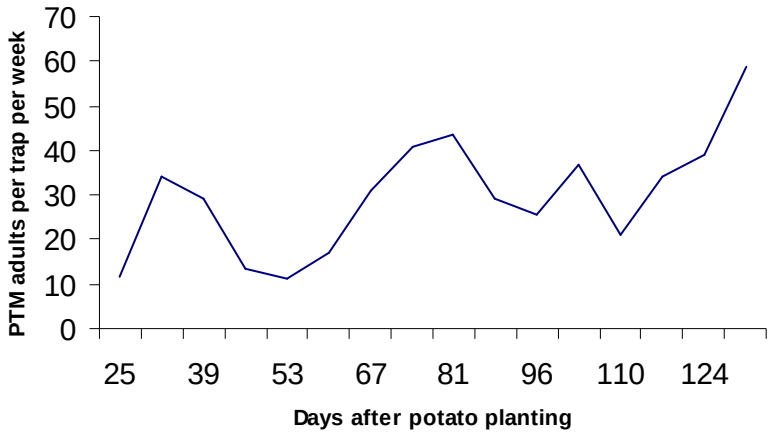


Fig. 1. Sex pheromone baited trap based monitoring of PTM in potato field at Melkassa in 2000/2001 (Bayeh, 2003).

Potato tuber moth larval populations were monitored weekly at the Melkassa Research Center on potato leaves (Bayeh, 2003). Larval population and the number of damaged leaves were recorded on randomly sampled 25 potato plants per plot. Both larval population and the leaf damage they caused increased with time and started to decline when most of the potato leaves entered senescence (Fig. 2).

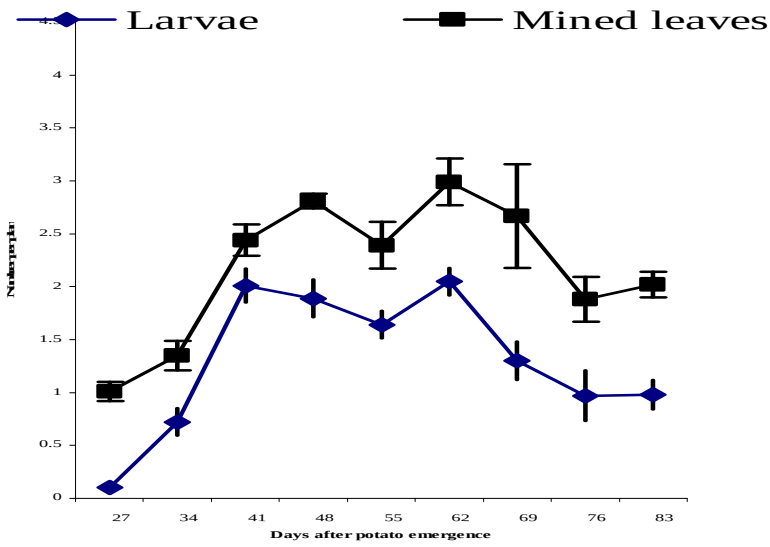


Fig. 2. Monitoring of PTM larval population and leaf damage on potato in 2000/2001 at Melkassa (Bayeh, 2003).

The population of PTM that build upon potato foliage has a direct aftermath on the level of infestation that may occur on developing tubers in the rhizosphere. When potato leaves start senescing, the larvae that develop in leaves find their way down to developing tubers by passing through cracks in the soil. Field infested tubers in turn serve as the nucleus for the multiplication of PTM in stores and for the subsequent carry over of the insect back to the field during the next cropping season. All these depend on the survival and development of PTM larvae in the foliage of potato plants. The survival and development of PTM larvae in potato foliage was studied in controlled growth chamber. Newly hatched larvae were transferred singly into individual Petri dishes containing undamaged leaves taken from potato plants at the pre-blossom and blossom stage. Data were collected on the survival and development of the larvae (n = 80) for the two crop stages. In general, larvae survived better on leaves of potato at blossom stage (Fig. 3). The finding compliments the earlier field observations (Fig. 2) where the larval population and the damage caused on potato leaves were higher during blossoming period. It was found that PTM had significantly longer larval and larva-adult development time on potato foliages at the pre-blossom stage than at the blossom stage (Fig. 4).

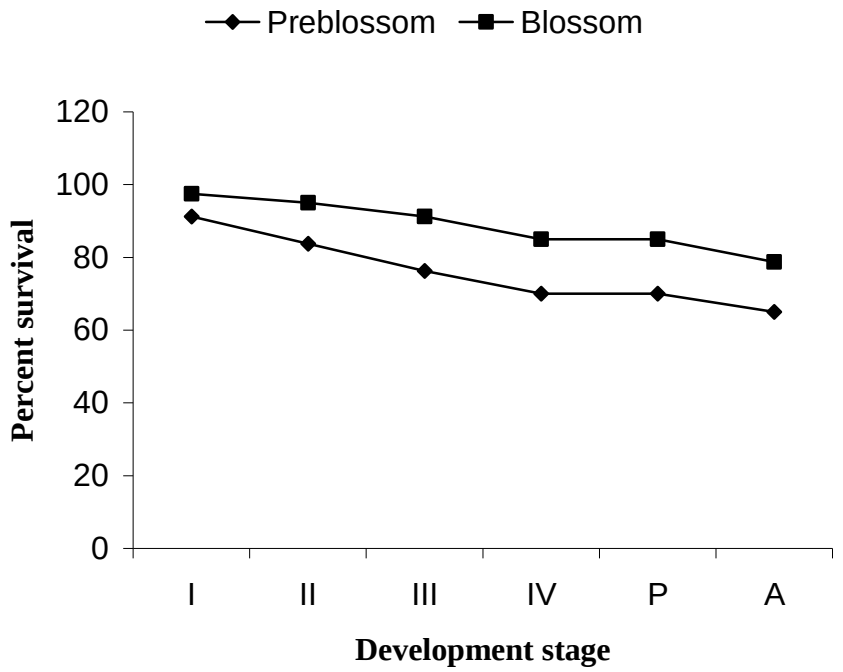


Fig. 3. Mean percentage survival of potato tuber moth larval instars (I-IV), pupae (P) and adults (A) in the leaves of potato plants sampled during pre-blossom and blossom stages (Bayeh, 2003).

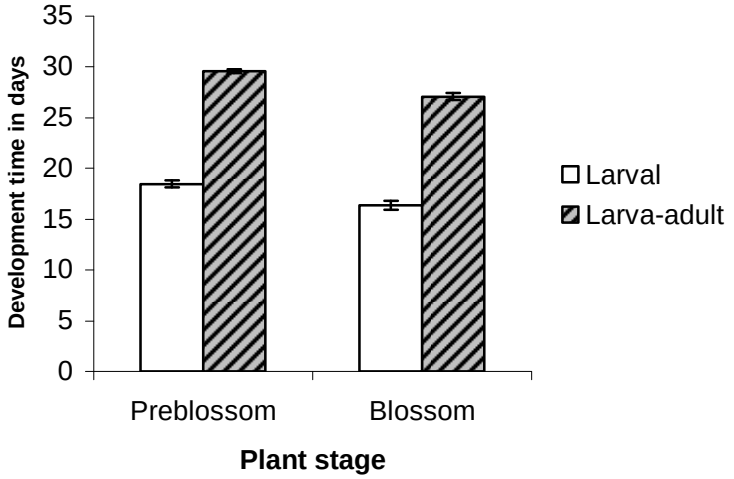


Fig. 4. Larval and larva to adult development time (days) of PTM on the leaves of potato taken at pre-blossom and blossom stages (Bayeh, 2003).

Improved storage of seed potato tuber in diffused light stores (DLS) has been demonstrated and introduced in various potato growing areas. However, DLS can never guard off insect pests like PTM. The major source of infestation often comes from tubers transported to DLS. There is always high accumulation of seed tuber per unit area in DLS than in an open field, thus the loss of tubers to the PTM is correspondingly high. The population of PTM in DLS was monitored at Holetta Research Center for three years (1988-91) using sex pheromone baited traps. The insect was found to be active and common all the year round. However, the count in July was significantly higher than in the other months. This was due to the length of storage period whereby the tubers in DLS were kept for about six months after harvest (Bayeh and Tadesse, 1992). The observation also showed that DLS stores with infested seed tubers are potential source of infestation of PTM for the next crop season.

Seed potato production by smallholder farmers has been well adopted and gaining importance in West and North West Shoa. The increase in production of seed tubers might have created an ideal environment for the multiplication and further spread of PTM to the surrounding areas. As a result, there are reports of the insect in places where it has never been reported before. Monitoring was carried out in DLS constructed by small farmers in the Dandi, Degem, Jeldu, and Walmera Woredas that have become the major sources of seed potato for the country at large. Data were collected fortnightly on the number of healthy and damaged sprouts per tuber on ten randomly selected tubers per shelf of the DLS. Each shelf was considered as a replication. The infestation of seed tubers by

PTM was found to be significantly higher in Walmera followed by Jeldu, while no damaged was observed in Dandi and Dagem (Fig. 5). Seed tuber production has longer history, about 15 to 16 years, in Walmera and Jeldu, while it is recent in Dandi and Degem. In general, these results indicated that PTM could become a threat in DLS following the increase in the production of seed tubers and number of DLS put up by farmers.

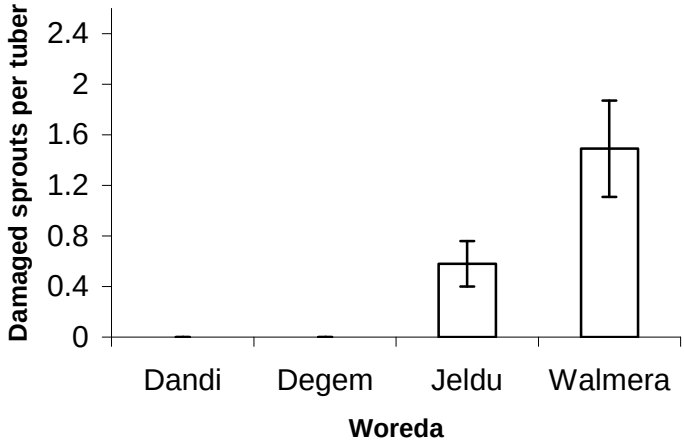


Fig. 5. Mean number of PTM damaged sprouts per tuber in DLS in four Woredas of West and North West Shoa (Bayeh, 2004).

The relative rates of tuber damage due to PTM were assessed in 30 different genotypes of potato grown at Alemaya, eastern Ethiopia (Sileshi and Teriessa, 2001). Field infestation in tubers ranged from 6-62% and significant differences were observed between genotypes in the degree of damage. Over 42% of the tubers were exposed to tuber moth infestation. Tuber infestation and rotting were found to be positively correlated with exposure. There was an overall increase by 93.2% in infestation and 96.3% in rotting in the exposed tubers over the covered ones. On average, 8.7% of the potato tubers were lost due to field infestation.

## PTM parasitism

A survey was conducted in potato production fields in the rift valley by deliberately exposing PTM larvae *in situ* in potato plants to natural enemies (Bayeh, 2003). Five parasitoid morphotypes were reared from PTM larvae recovered from mines in potato leaves. The most common parasitoid was the ichneumonid, *Diadegma mollipla* (Hlmgr), which accounted for about 66.2% of the recovered parasitoids. On the other hand, the level of parasitism was not

significantly different among the two plant stages and the unspecified plant stage of potato in farmers' fields (Fig. 6).


Fig. 6. Percentage parasitism of PTM larvae in the foliage of potato plants at pre-blossom, blossom and unspecified stages (after Bayeh, 2003).

# Control measures for PTM

## Screening of botanicals

Different botanicals were screened for the control of PTM in DLS at Holetta Research Center (HARC, 1997). Fifty potato tubers of the variety Wechecha were placed in a plastic box and replicated three times for each treatment. Powdered flowers of pyrethrum, *Chrysanthemum cineraraefolium* and leaf powder of all the other tested plants were dusted on potato tubers at 35 g/50 tubers. Uniform coating of all the tubers was ensured by thoroughly shaking them with dust in a plastic box. Aqueous neem seed extract was prepared from 500 g dried and crushed seed that was suspended in a bucket of water tied in a cloth. After 12 hours, the seed materials were removed and squeezed and the solution was taken up to 10 litters. The neem (*Azadirachta indica)* seed extract at 5% concentration and diazinon 60% EC (5 ml in 10 litres of water) solution were prepared and the test tubers were dipped for about one minute before storage. All the treated tubers were exposed to natural PTM infestation. Evaluations made after 120 days showed that the powders from neem seeds, endod seeds and pyrethrum flowers significantly reduced ($P<0.05$) tuber damage when compared with the untreated check and the standard insecticide, diazinon 60% EC (Table 2).

Table 2. Control of PTM with botanical powders in DLS at Holetta (HARC, 1997).

| Treatment (botanical powders) | | Percentage damage after 4 months | |
|---|---|---|---|
| **Common ame** | **Scientific name** | **Sprouts damaged** | **Tubers damaged** |
| Pyrethrum-flower | *Chrysanthemum* sp. | 0.31.b | 3.3ab |
| Endod-Seed | *Phytolacca dodecandra* | 1.62ab | 8.0ab |
| Endod-Leaf | *Phytolacca dodecandra* | 8.23ab | 3.3ab |
| Yewof kolo-leaf | *Lantana camara* | 2.36ab | 3.3ab |
| Neem-seed | *Azadirachta indica* | 0.57ab | 1.3b |
| Neem-leaf | *Azadirachta indica* | 5.41ab | 1.3b |
| Nech Beharzaf-leaf | *Eucalyptus globules* | 8.83a | 2.0b |
| Bisana-leaf | *Croton macrostachys* | 2.69ab | 4.7ab |
| Pepper-leaf | *Piper capense* | 2.85ab | 4.0ab |
| Mexican marigold-leaf | *Tagetus minuta* L | 2.85ab | 4.0ab |
| Basudin (diazinon) 60% EC | | 3.86ab | 4.7ab |
| Control | | 5.02ab | 7.3a |
| CV% | | 55.3 | 34.4 |

Means followed by different letters within a column are significantly different from each other ($P < 0.05$).

In the years 2000/01 and 2001/02, a number of botanicals and Bt *(Bacillus thuringiensis* Kurstaki) were evaluated for the control of PTM both in the field and store. The trials were carried out at Holetta Research Centre and at Shashemene (HARC, 2003). The storage experiments started in November in both locations, the time farmers start storing tubers for seeds (October/ November to June). Neem seed, neem leaf and pyrethrum flower were crushed and water extracted for 24 hours before application. The concentrations of the dipping solutions in water were: Basudin 60% EC solution at 5 ml /10 litres of water, 500 g powder of neem seeds in 10 litres of water, 70 g powder of pyrethrum flower in 10 litres of water, 70 g powder of neem leaf in 10 litres of water, Bt solution at 5 g/ 10 litres of water. Tubers without any sign of PTM damage were dipped in the different solutions for 10 min. Treated tubers were put in separate plastic boxes and stored in DLS. The results from the experiments conducted in 2000/01 are reported here. Dipping of potato tubers in aqueous solutions of pyrethrum flower or neem leaf powder were found to be effective in significantly reducing sprout damage by the PTM in both places. In general, pyrethrum flower gave the best protection to the seed tubers (Fig. 7). Similar procedures were followed to evaluate the efficacy of the botanicals and *Bt* against PTM in the field. Extracts were prepared from neem seed, pyrethrum flower and neem leaf and solutions of Basudin 60% EC and *Bacillus thuringiensis* Kurstaki. The aqueous solutions were applied after making a pre-spray count. Post-spray counts were made after 96 hr. In 2002, the post-spray

counts made after 96 hrs showed that diazinon 60% EC treated plots had the lowest population of PTM (Fig. 8).

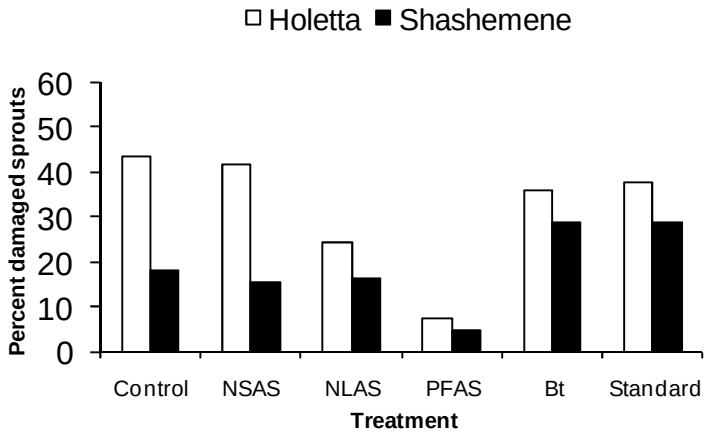


Fig. 7. Mean percentage PTM damaged sprouts of potato tubers treated with different botanicals and Bt. in DLS at Holetta and Shashemene in 2001/02. (NSAS = neem seed aqueous solution; NLAS = neem leaf aqueous solution; PFAS = pyrethrum flower aqueous solution; Bt = *Bacillus thuringiensis;* standard = diazinon 60% EC) (after HARC, 2003).

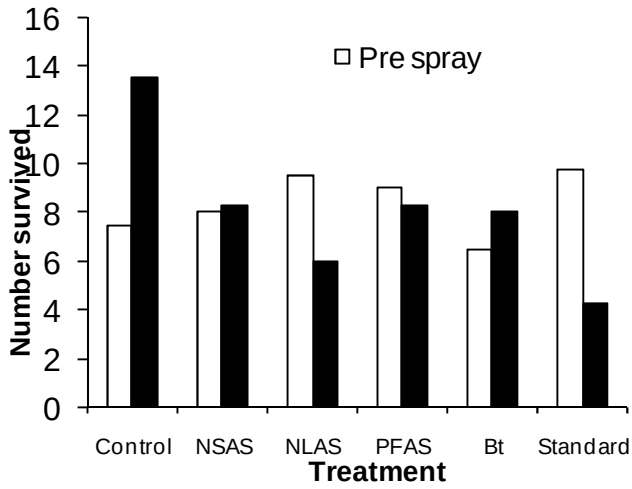


Fig. 8. Effect of spray of different botanicals and Bt on the population of PTM at Holetta during off-season, 2002. (NSAS = neem seed aqueous solution; NLAS = neem leaf aqueous solution; PFAS = pyrethrum flower aqueous solution; Bt = *B. thuringiensis*; standard = diazinon 60% EC) (after HARC, 2003).

## Studies on red ants on potato

Crow and Shitaye (1977) and Crow *et al.* (1977) reported that the red ant (*Dorylus* sp.) was a very serious pest on vegetable crops grown at high altitudes. Red ants damage potato plants by scraping the phloem tissues of the roots and destroy root hairs. Such potato plants wilt and die. If the insect appears late in the cropping season, they bore hole and eat out the starch from the developing tubers. Thus, the insect causes direct loss as such kind of damaged tubers are unmarketable. However, the insect has not been reported in major potato growing areas such as Awassa, Shashemene and Shamena, which are situated at altitudes of 1680, 1800 and 2120 masl, respectively. Most of the farmers in Walmera, Degem, Jeldu and Dandi Woredas who were interviewed during a survey responded that the pest is more serious in dry soils. However, most of the farmers in Degem responded that the pest is problematic in wet conditions. About 63% of the farmers responded that the insect is active at any time of the day; 16% said it is active in the morning and another 16% said that it is active in the afternoon, and 5% said it is active in the evenings. Farmers' estimations of the extent of damage on potato by the red ants varied (Table 3). Most of the farmers estimated red ant damage on potato between 0 and 50%. In Degem (North West Shoa) 29% of the farmers claimed up to 100% damage. However, results from sampling of 10 potato plants per field carried out on a total of 8, 8, 17 and 15 farmers' fields in Galessa, Jeldu, Walmera and Dagem, respectively, did not correspond with the farmers' estimations (Fig. 9). The percentage of root damage did not exceed 25% suggesting that farmers overestimated the damage by red ants. The survival of workers of red ants on various parts of potato was studied by offering pieces of potato roots, stem, or tubers to the red ants in plastic Petri dishes covered with tight lids, but ventilated. The control groups were not given any food. The worker ants were collected from active colonies in potato plots and transferred at the rate of 10/ Petri dish. The mortality of the ants was recorded after three days. The least mortality was recorded in the ant groups provided with roots (Fig. 10). The result suggests that control of red ants in potato should focus on delivering the control agent to the root zone of the potato plants.

Table 3. Farmers' estimations of red ant damage on potato plants in 2001 (HARC, 2001).

| Damage level (%) | Percentage of respondents | | | |
|---|---|---|---|---|
| | Galessa | Jeldu | Walmera | Degem |
| 0 | 0 | 0 | 9.5 | 22.0 |
| ≤25 | 67.0 | 54.6 | 28.6 | 12.0 |
| 26-50 | 33.0 | 31.8 | 23.8 | 15.0 |
| 51-75 | 0 | 13.6 | 28.6 | 22.0 |
| 76-100 | 0 | 0 | 9.5 | 29.0 |

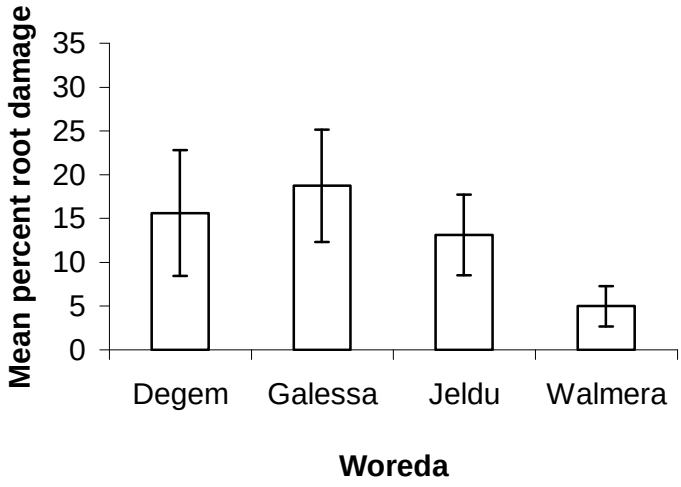


Fig. 9. Percentage damage of potato roots by red ants in four seed potato growing Woredas of the central highlands (after Bayeh, 2006, unpublished).

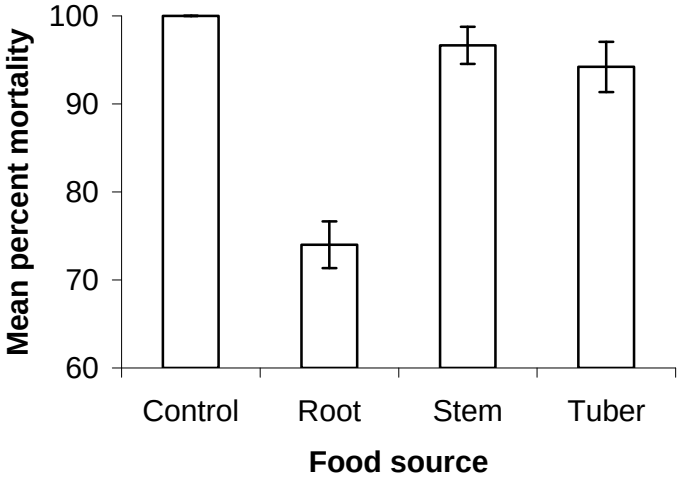


Fig. 10. Percentage mortality of red ant workers provided different parts of potato plant *in vitro* after 3 days (after Bayeh, unpublished).

## Aphids on potato

Among the species of aphids known to transmit potato leaf roll virus (PLRV), the most important virus diseases of potato, only the bean aphid (*Aphis fabae*), the potato aphid (*Macrosiphum euphorbiae*) and the green peach aphids (*Myzus persicae*) were commonly recorded in potato fields in Ethiopia. In addition, the

Brassica aphid, *Brevicoryne brassicae*, the rose flower aphid, *Macrosiphum rosae* and *Aphis* spp. are commonly found in and around potato fields. However, the Brassica aphid, which was by far the most common aphid species, was reported not to transmit PLRV (Bayeh and Tadesse, 1992).

# Enset

## Insect pests recorded

Only a few insects have been recorded attacking enset (Table 4). However, enset root mealybug has become the most important (Tsedeke, 1988; Addis, 2005; Eyob, 2006). The enset root mealybug, *Cataenococcus ensete* William and Matile-Ferrero (Homoptera: Pseudococcidae), is a major pest of enset in the South and southwestern parts of the country (Addis, 2005). It has been collected and reported from Wonago as a new record for Ethiopia (Tsedeke, 1988). *C. ensete* has hitherto been referred to as *Paraputo* sp. which is now sucked as a junior synonym of *Cataenococcus* sp. (Williams and Matile-Ferrero, 1999). *Pentalonia nigrnervosa, Poeicilcarda nigrineervis* and *Planococcus* spp. were frequently found on wilted and healthy plants (Adhanom and Emana, 1987a; 1987b). These insects have been implicated in the transmission of the enset bacterial wilt (Eshetu, 1981). Adhanom and Emana (1987a; 1987b) also reported outbreak of unidentified lepidopterous larvae in Wolaita area especially in the low lands below 1500 masl.

Table 4. Insect pests of enset recorded in Ethiopia.

| Scientific name | Common name | Status | References |
|---|---|---|---|
| **Homoptera** | | | |
| **Aleyrodidae** | | | |
| *Bemisia tabaci* (Gennadius) | Tobacco whitefly | minor | 65 |
| **Aphididae** | | | |
| *Pentalonia nigrnervosa* Coquerel | Banana aphid | minor | 9, 10, 40, 65 |
| **Diaspididae** | | | |
| *Chrysomphalous aonidium* (L.) | Purple scale | minor | 65 |
| **Cicadellidae** | | | |
| *Poeicilocarda nigrinervis* Stal | Black stripped jassid | minor | 9, 10, 40 |
| **Pseudococcidae** | | | |
| *Catenococus ensete* Will. Matile-Ferr. | Enset root mealybug | major | 3,4,5,6,7,41, 62,65,67 |
| *Planococcus ficus* | Root mealybug | unknown | 9, 10, 40 |

# Enset root mealybug

## Basic studies

Addis (2005) conducted a survey in 163 sites of 25 districts of southern Ethiopia from July 2004 to December 2004 and recorded the root mealybug in Sidama, Gedeo, Gurage, Bench, Kembata Tembaro, Hadyia zones and Amaro and Yem districts. However, the level of infestation was found to be high only in Amaro (100%), Gedeo (66.7%), Sidama (61.5%) and Bench (57.1%). The highest number of mealybugs (81mealybugs/ plant) was recorded in Gedeo zone and the lowest (3.3 mealybugs/ plant) in Yem district. Maji, Gamo Goffa, Sheka, West Shoa, and Jimma were free from enset root mealybugs. The enset root mealybug is known by different local names in different areas; '*Tsete'* in Gedeo, '*Chea'*, '*Churcha'* and '*Hufaro'*, in Sidama, '*Buno'*, '*Osk'*, '*Oote'* and '*Dachu'* in Bench languages. Although *C. ensete* was observed at elevations ranging from 1,054-2,977 masl, its infestation was severe between 1,400 and 2,200 masl. The highest level of infestation (53.6%) was recorded between 1,600 and 1,800 masl (Fig. 3); and the lowest above 2,200 masl and below 1,400 masl. The insect attacks enset of all age groups, but it is more serious on 2 to 4 years old enset plants. *C. ensete* was found exclusively on the roots and corm of enset and infested plants have less number of roots, retarded growth, and lack of vigor and subsequently die especially when there is moisture stress. Early infestation by *C. ensete* can be easily overlooked because effects on the above ground part appear lately after extensive damage on the roots and corm had occurred. On the other hand, varying levels of mealybug infestations were recorded on 211 different farmers' enset cultivars (Addis, 2005).

## Biology of enset root mealybug

The enset root mealybug has different development stages: (1) bright-orange to yellow-orange colored "crawlers" or rapidly moving first-instar, (2) the settled first-instars that secrete wax that gives the body a whitish appearance, (3) second and third instars that begin to develop distinct lateral and posterior cerarii, increase in body size, and start to produce large amounts of honeydew and (4) the pre-ovipositing adult female. Males are unknown for *C. ensete* and none were observed during this study too. The viviparous females produced 253$\pm$17.4 nymphs/ female. The average daily fecundity was six nymphs (Addis, 2005). The average duration of the first, second and third instar nymphs was 16.2 $\pm$ 0.5, 18.2 $\pm$ 0.7 and 19.8 $\pm$ 0.5 days, respectively (Addis, 2005). The average life span of the adult female was 49.95 $\pm$ 0.5 days with a range of 47 to 53 days. Thus, the estimated generation time of the enset root mealybug was 94-113 days with estimated three generations per year. The body size of the different nymphal stages ranged from 0.5-2.7 mm long (Table 5). The body size of the adult

mealybug ranged from 2.9-4.0 mm in length. According to Addis (2005), the enset root mealybugs encountered in the field were larger in size than those reared in the laboratory. This might be due to the unfavourable environmental conditions in the laboratory compared to their natural habitat. The mealybugs survived well when reared on whole pumpkin and completed their growth to the adult stage. It was observed that adult female mealybugs could not survive for more than three weeks in the soil in absence of plant materials to feed on (Addis, 2005).

## Distribution of enset root mealybug on enset and the soil

The majority (79%) of the enset root mealybugs inhabited the roots and the remaining (21%) was found on the corms (Addis, 2005). Enset root mealybugs were found up to a soil depth of 60-80 cm away from the corm. However, root density as well as the number of mealybug decreased with increasing soil depth. About 99% of the mealybugs were found in the upper 40 cm soil layer. In addition, about 90% of the mealybugs were collected within a 60 cm radius from the plants. On the other hand, 59% of the mealybugs were found on the upper half of the corm. Most of the enset root mealybugs were found within 20 cm radius from the corm (about 63%). Hence, sampling a 20 x 20 x 20 cm cube of soil and roots adjacent to the corm will capture a large percentage of the total root mealybug population on a plant. The proposed assessment method will provide field technicians and researchers with a simple tool to assess population numbers of the enset root mealybugs. It was found that the relationship between plant growth parameters (plant height, pseudostem circumference, fresh root weight and fresh shoot weights) and the population density of root mealybugs was negative (Fig. 11).

## Dissemination of enset root mealybugs to new areas

It was observed that some of the enset nurseries found in southern Ethiopia (Yirgachefe and Wonago districts) were highly infested by mealybugs. Some development organizations (aid and government) have been procuring enset suckers from such sites and distribute to different areas of the country where farmers are trying to adopt enset production. Thus, the use of infested suckers has been the major means of spread for the enset root mealybug to new areas.

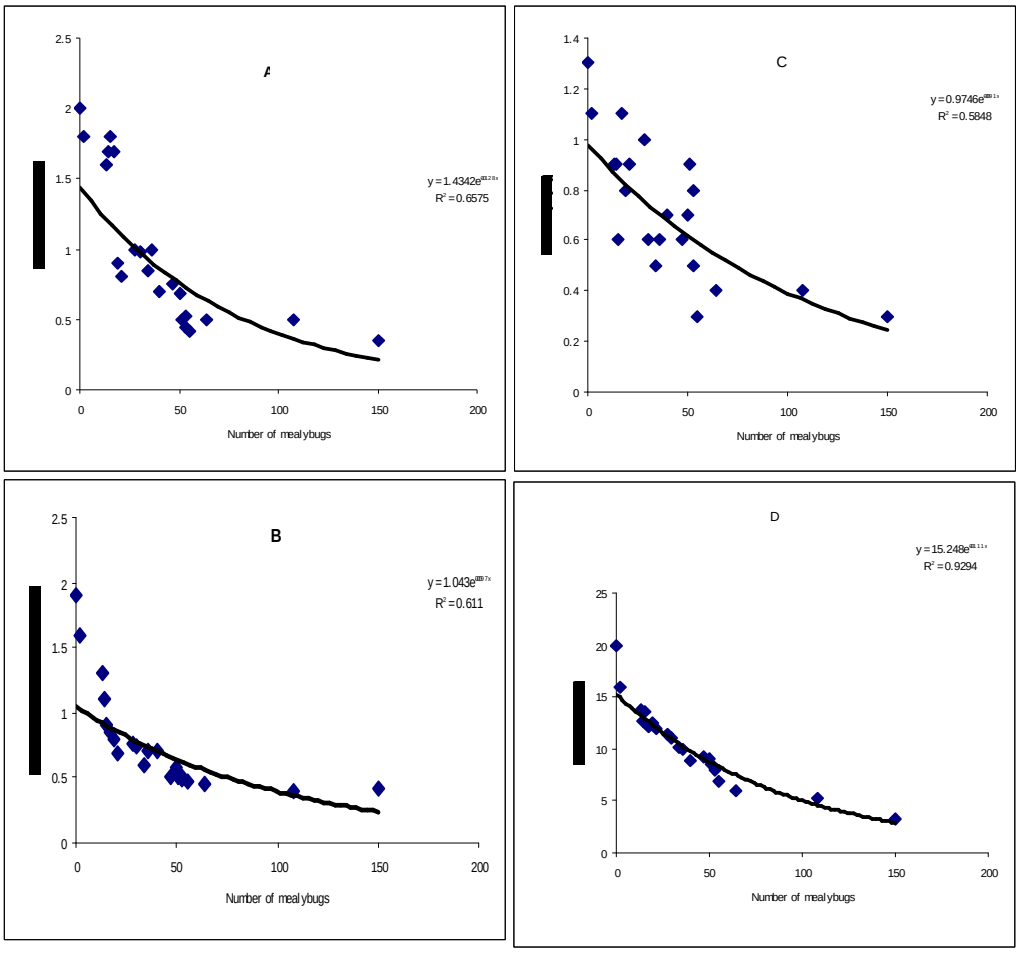


Fig. 11. Relationship between enset root mealybug population and enset plant height (A) and pseudostem circumference measured at soil level (B), enset shoot fresh weight [i.e. leaf + corm + pseudostem fresh weight] (C) and root fresh weight (D). (n=22) (after Addis, 2005).

Table 5. Mean duration and body size of different stages of the enset root mealybug (*Cataenococcus ensete*) (after Addis, 2005).

| **Insect stage** | **Mean days** | **Range** | **Body length (mm)** | **Range** |
|---|---|---|---|---|
| First instar | 16.2 ± 0.5 | 13-19 | 0.79 ± 0.04 | 0.5-1.2 |
| Second instar | 18.2 ± 0.7 | 13-25 | 1.71 ± 0.03 | 1.5-1.9 |
| Third instar | 19.8 ± 0.4 | 16-23 | 2.46 ± 0.03 | 2.2-2.7 |
| Adult | 50.0 ± 0.5 | 46-53 | 3.31 ± 0.07 | 2.9-4.0 |
| Total duration | 103.9 ± 1.1 | 94-113 | | |

Mean ± standard error

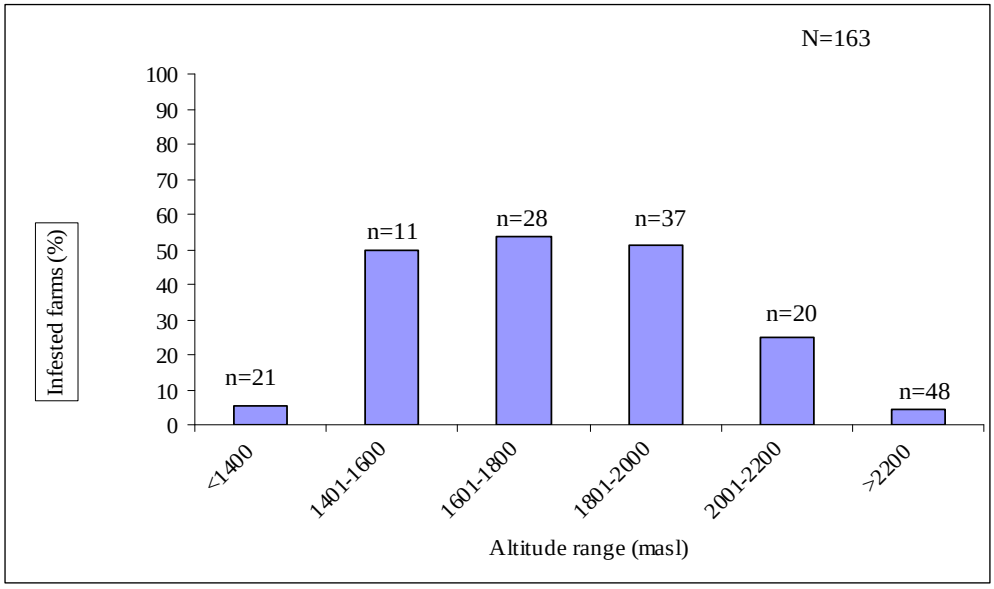


Fig. 12. Incidence of enset root mealybug *(Cataenococcus ensete*) at different altitudes (Addis, 2005).

Table 6. Population density of enset root mealybug in some localities of southern Ethiopia.

| **Areas surveyed** | **No. of farms visited** | **Sites with mealybugs (%)** | **No. of adult mealybugs/ plant** |
|---|---|---|---|
| Gedeo | 21 | 66.7 | 81.2 |
| Sidama | 26 | 61.5 | 5.2 |
| Amaro | 6 | 100 | 9.7 |
| Hadyia | 12 | 9.3 | 3.5 |
| Bench | 7 | 57.1 | 1.5 |
| Keffa | 7 | 29.6 | 9.0 |
| Gurage | 12 | 9.3 | 9 |
| Kembata Tembaro | 12 | 25 | 4.7 |
| Yem | 6 | 17.7 | 3.3 |

# Control measures

## Cultural methods

Farm yard manure treatments on infested plants did not reduce the population density of the pest, however, the plants grew and developed better when received the manure which enabled them to withstand the damage by the insect (Addis and Tesfaye, 2002).

## Botanicals

The efficacy of seeds of *Azadirachta indica, Melia azedarach, Phytolaca dodecandra, Schinus molle,Milletia ferrugenia* and *Maesa lanceolata;* seeds and leaves of *Chenopodium ambrosiodes, Tephrosia vogelli, Nicotina tabacum*, and *Maesa lanceolata* were evaluated against the enset root mealybugs in Petri dish and greenhouse experiments (Eyob, 2006). *M. ferruginea* seed-water suspensions extracted at the rate of 10% (w/v) and *Nicotina tabacum* leaf-water suspension extracted at the rate of 30% (w/v) were found to be toxic to the pest under laboratory conditions (Table 7). The $LC_{50}$ and $LC_{90}$ were 40.39 mg and 77.62 mg for *M. ferruginea* and 237 mg/ml and 284.4 mg for *N. tabacum*, respectively. In the pot experiment, drenching the soil around the roots of infested young enset plants with seed water suspensions of 10% *M. ferruginea* caused about 66% mortality. However, *M. ferruginea* was found to be inferior to the synthetic insecticide diazinon. Two applications of *M. ferruginea* improved its efficacy and raised the level of mortality to about 79%. On the other hand, dipping of infested enset seedlings in *M. ferruginea* seed-water suspensions of 10% caused 44% mortality, which is significantly higher ($P<0.05$) than the other botanicals tested and the untreated check. The study indicated that one application of milletia seed water suspension can not satisfactorily control the enset root mealybugs. Combinations of dipping young enset seedlings and repeatedly drenching of the root zone of infested plants with the milletia seed water suspension may be used as part of IPM for the enset root mealybug.

## Chemical control

The efficacy of chlorpyrifos, diazinon, dimethoate, endosulfan, fenitrothion and malathion was evaluated against the enset root mealybug under greenhouse and field conditions by drenching the soil (Eyob, 2006). In the greenhouse, diazinon and chlorpyrifos provided 100% and 97% mortality of the pest, respectively (Table 8). The other insecticides were also significantly different from the untreated check, but they caused mortality less than 84%. Chlorpyrifos and diazinon were equally effective on enset root mealybug in the field with >90% mortality of the adult within 14 days after application (Table 9). The percentage mortality increased over time reaching 98% following 45 days after treatment application. Malathion, dimethoate, endosulfan and fenitrothion were less effective. Tesfaye (2003) also indicated that chlorpyrifos 48% EC was effective against the enset root mealybug. However, yellowing of plants was observed in some of the plants treated with chlorpyrifos, diazinon, and malathion (Eyob, 2006). It was suggested that drenching with insecticides should be done on moist soils.

Table 7. Mean mortality of enset root mealybug when treated with water suspensions of different plant materials in Petri dish experiment (Eyob, 2006).

| **Treatments (4ml/5cm$^3$ of soil in the Petri dish)** | **Percentage mortality hours after treatment** | | | | | |
|---|---|---|---|---|---|---|
| | **24 hrs** | | **48 hrs** | | **72 hrs** | |
| | **Observed** | **Corrected.** | **Observed** | **Corrected** | **Observed** | **Corrected** |
| *Chenopodium ambrosiodes* | 6.7$^{d}$ | 0.10 | 13.3$^{d}$ | 3.40 | 19.9$^{d}$ | 9.61 |
| *Maesa lanceolata* (leaf) | 10.0$^{d}$ | 3.40 | 13.3$^{d}$ | 3.40 | 23.3$^{cd}$ | 13.01 |
| *Maesa lanceolata* (seed) | 16.7$^{d}$ | 10.11 | 23.3$^{cd}$ | 13.41 | 29.9$^{cd}$ | 19.62 |
| *Azadirachta indica* | 16.7$^{d}$ | 10.11 | 23.3$^{cd}$ | 13.41 | 29.9$^{cd}$ | 19.62 |
| *Phytolaca dodecandra* | 10.0$^{d}$ | 3.40 | 23.3$^{cd}$ | 13.41 | 39.3$^{c}$ | 29.03 |
| *Melia azedarach* | 16.6$^{d}$ | 10.11 | 23.3$^{cd}$ | 13.41 | 34.0$^{c}$ | 23.72 |
| *Schinus molle* | 13.3$^{d}$ | 6.70 | 36.6$^{c}$ | 26.73 | 43.3$^{c}$ | 33.03 |
| *Tephrosia vogelli* | 16.7$^{d}$ | 10.11 | 29.9$^{cd}$ | 20.02 | 53.3$^{b}$ | 43.04 |
| *Nicotina tabacum* | 63.4$^{c}$ | 56.83 | 86.6$^{b}$ | 76.77 | 96.6$^{a}$ | 85.78 |
| *Millettia ferruginea* | 80.0$^{b}$ | 73.42 | 100.0$^{a}$ | 90.02 | - | - |
| Diazinon 60% EC | 100.0$^{a}$ | 93.45 | - | - | - | - |
| Untreated control | 6.6$^{d}$ | - | 9.9$^{d}$ | - | 10.3$^{d}$ | - |
| CV (%) | 21 | - | 18.4 | - | 14.5 | - |

Means followed by the same letter in the columns are not significantly different from each other according to Tukey's HSD test, P<0.05.

Table 8. Mean mortality of enset root mealybug due to synthetic insecticides under greenhouse conditions (after Eyob, 2006).

| **Treatments** | **Observed mortality (%)** | **Corrected mortality (%)** |
|---|---|---|
| Diazinon 60% EC | 100. ± 0.0 $^{a}$ | 84.13 |
| Chlorpyrifos 48% EC | 97.6 ± 1.0 $^{a}$ | 80.23 |
| Malathion 50% EC | 83.2 ± 1.9 $^{ab}$ | 67.30 |
| Fenitrothion 50% EC | 76.8 ± 2.3 $^{b}$ | 60.89 |
| Endosulfan 50% EC | 74.4 ± 4.1 $^{b}$ | 58.53 |
| Dimethoate 40% EC | 64.8 ± 3.4 $^{b}$ | 48.87 |
| Control (untreated) | 16.0 ± 3.5 $^{c}$ | - |
| CV | 16% | |

Means followed by the same letter within a column are not significantly different from each other, Tukey, P <0.05.

Table 9. Mean mortality and survival of enset root mealybugs on enset seedlings treated with different insecticides under farmers' field conditions (Eyob, 2006).

| Treatments | Mean mortality (%)† | | | Mean No. of surviving mealybugs† | | |
|---|---|---|---|---|---|---|
| | 15 days | 30 days | 45 days | 15 days | 30 days | 45 days |
| Diazinon 60 %EC | 96.5±1.4 [a] | 97.7±1.2 [a] | 98.1±1.1 [a] | 0.9 ± 0.4 | 0.50±0.3 | 0.75±0.4 |
| Chlorpyrifos 48%EC | 93.7±1.9[a] | 95.4±1.3 [a] | 97.9±1.2 [a] | 1.1 ± 0.4 | 1.57±0.5 | 0.50±0.3 |
| Malathion 50 %EC | 75.3±1.6 [b] | 67.4±2.2 [b] | 49.7±1.6 [c] | 4.0 ± 0.5 | 7.70±1.0 | 7.90±1.0 |
| Endosulfan 50%EC | 61.3±2.7 [c] | 58.9±1.9 [c] | 50.8±3.0 [c] | 7.3 ± 1.8 | 7.25±1.8 | 9.60±2.5 |
| Dimethoate 40 %EC | 53.5±1.4 [c] | 60.2±1.9 [c] | 64.8±2.9 [b] | 7.1 ± 1.5 | 8.00±0.8 | 5.50±1.3 |
| Fenitrothion 50 %EC | 61.9±3.7 [c] | 55.1±1.9 [c] | 51.0±1.8 [c] | 7.9 ± 0.9 | 9.20±2.2 | 9.20±1.3 |
| Control | - | - | - | 34.2 ±5.2 | 58.9±12.1 | 53.6±12.6 |
| CV (%) | 14.7 | 8.2 | 11.5 | - | - | - |

†per sample of soil

Means followed by the same letter within a column are not significantly different; Tukey's HSD test at P <0.05.

Table 10. Mean mortality of enset root mealybugs on enset seedlings treated twice with different insecticides under farmers' field conditions (Eyob, 2006).

| Treatment | Mortality % | | |
|---|---|---|---|
| | 15 days | 30 days | 45 days |
| Diazinon 60 % EC | 100.0 ± 0.0 [a] | 100.0 ± 0.0 [a] | 99.1 ± 0.9 [a] |
| Chlorpyrifos 48 % EC | 98.4 ± 1.6 [a] | 98.9 ± 1.1 [a] | 99.2 ± 0.8 [a] |
| Malathion 50 % EC | 87.1 ± 2.1 [b] | 78.3 ± 2.6 [b] | 64.9 ± 4.2 [bc] |
| Endosulfan 50% EC | 73.4 ± 0.6 [c] | 61.0 ± 1.4 [c] | 52.8 ± 0.7 [c] |
| Fenitrothion 50% EC | 71.4 ± 1.6 [c] | 62.2 ± 3.1 [c] | 54.1 ± 1.1 [c] |
| Dimethoate 40% EC | 67.3 ± 1.0 [c] | 75.6 ± 1.1 [b] | 74.7 ± 1.6 [b] |
| Control | - | - | - |
| CV (%) | 9.4 | 21.0 | 9.8 |

Means followed by the same letter within a column are not significantly different; according to Tukey's HSD test at, P<0.05.

In another study, chlorpyrifos, aluminium phosphid (tablets) and malathion 50% EC originating from Admitulu Pesticide Processing Sc. Co. provided better control (Addis and Tesfaye, 1995c).

# Sweet potato

## Pests recorded

Insect pests recorded on sweet potato in Ethiopia are presented in Table 11. Among these, only the sweet potato weevil (*Cylas puncticollis*) and the sweet

potato butterfly (*Acraea acerata)* are the major pests (Crowe *et al.*, 1977; Emana and Adhanom, 1989; Ejigu, 1995; Azerefegne, 1999; Endrias, 2003) which received better research attention.

Table 11. Insect pests recorded on sweet potato in Ethiopia.

| Scientific name | Common name | Status | References |
|---|---|---|---|
| **Orthoptera** | | | |
| **Acrididae** | | | |
| *Aiolopus simulatrix* (Walker) | Clay grasshopper | Unknown | 65 |
| *Atractomorpha acurtepennis gerasteckeri* (I. Boliver) | Sweet potato grasshopper | Unknown | 65 |
| **Homoptera** | | | |
| **Aleyrodidae** | | | |
| *Bemisia tabaci* (Gennadius) | Sweet potato white fly | Unknown | 7, 35 |
| **Cicadellidae** | | | |
| *Empoasca fascialis* (Jacoby) | Cotton leafhopper | Minor | 65 |
| **Heteroptera** | | | |
| **Corediae** | | | |
| *Cletus fuscescens* (Walker) | Cletus bug | Unknown | 65 |
| L**ygaeidae** | | | |
| *Garptostethus rufus* Distant | Red sweet potato bug | Unknown | 65 |
| *Garptostethus servus* (Fabricius) | Red sweet potato bug | Unknown | 65 |
| *Lygaeus negus* Distant | Red sorghum bug | Unknown | 65 |
| **Miridae** | | | |
| *Helopeltis schoutedeni* (Reuter) | Cotton helopeltis | Unknown | 65 |
| *Taylorilygus simyoni* (Reut.) | Sweet potato bug | Unknown | 65 |
| Pentatomidae | | | |
| *Calidea bohemania* (Stal) | Blue bug | Unknown | 65 |
| *Calidea dudecinpunctata* (Fabricius) | Blue bug | Unknown | 65 |
| *Carbula recurva* Distant | Carbula bug | Unknown | 65 |
| *Durmia conjugens* (Germar) | Durmia bug | Unknown | 65 |
| *Macroraphis acuta* Dallas | Acute stink bug | Unknown | 65 |
| *Nezera viridula* (Linnaeus) | Green stink bug | Unknown | 65 |
| *Veteran abyssinica* Lethiery | Linseed stink bug | Unknown | 65 |

Table 11. Contd.

| Scientific name | Common name | Status | References |
|---|---|---|---|
| **Coleoptera** | | | |
| **Curculionidae** | | | |
| *Cylas puncticollis* Bohemian | Sweet potato weevil | Major | 2,7,8,13,31,35,36,37,38, 39,53,63, 65 |
| *Cylas compressus Hartman* | Sweet potato weevil | Unknown | 31, 65 |
| *Alicidodes dentipes (*Oliver*)* | Striped sweet potato weevil | Unknown | 31, 35 ,65 |
| *Alicidodes humerous* Harold | Striped sweet potato weevil | Unknown | 65 |
| *Blosyrus rugulosus abyssinicus* Aurvillius | Rough sweet potato weevil | | 31, 65 |
| *Blosyrus rugulosus* Aurvillius | Rough sweet potato weevil | | 65 |
| **Chrsysomelidae** | | | |
| *Aspidomorpha apicalis* (Klug) | Tortoise beetle | Unknown | F |
| *Aspidomorpha areata* Klug | Tortoise beetle | Unknown | F |
| *Aspidomorpha areata var nigripennis* | Tortoise beetle | Unknown | F |
| *Aspidomorpha cincta* Fabricius | Tortoise beetle | Unknown | 65 |
| *Aspidomorpha quadrimaculata* (Oliver) | Tortoise beetle | Minor | 65 |
| *Aspidomorpha tecta* (Beheman) | Sweet potato tortoise beetle | Minor | 7, 31, 35, 65 |
| *Conchyloctenia hybrida* (Beheman) | Conchylo tortoise beetle | Unknown | 65 |
| *Conchyloctenia illota* (Beheman) | Conchylo tortoise beetle | Unknown | 65 |
| *Conchyloctenia punctata* | Conchylo tortoise beetle | Unknown | 65 |
| **Coccinellidae** | | | |
| *Chnootriba similis* (Thnb.) | Tef epilahna | Unknown | 65 |
| **Lagriidae** | | | |
| *Lagria villosa* Fabricius | Metallic beetle | Unknown | 7, 31, 35, 65 |
| *Chrysolagria cuprina* (J. Thompson) | Cuprina beetle | Unknown | 65 |
| *Sesselia pusilla* | Black leaf beetle | Unknown | 65 |
| **Lepidoptera** | | | |
| **Lyonetiidae** | | | |
| *Beddelia somnulentella (*Zeller*)* | Sweet potato leaf miner | Sporadic | 7, 11, 31, 35, 65 |
| **Nymphalidae** | | | |
| *Acarea acerata* Hew. | Sweet potato butterfly | Major | 1,7,20,21,31, 33,3435, 36, 39,54,64, 65 |
| **Sphinigidae** | | | |
| *Agrius convolvuli (*Linnaeus) | Sweet potato hawk moth | Minor | 7, 31, 35, 65 |

Table 11. Contd.

| Scientific name | Common name | Status | References |
|---|---|---|---|
| *Hippotion celerio (*Linnaeus) | Vine hawk moth | Unknown | 65 |
| *Hyles lineate* (Fabricius) | Silver stripped hawk moth | Unknown | 31, 65 |
| **Noctuidae** | | | |
| *Diachrysia orichlacea* (Fabricius) | Golden plusia | Unknown | 65 |
| *Spodoptera littoralis* Boisduval | Cotton leaf worm | Unknown | 65 |
| *Ctenoplussia limbirena* Guenee | Plusia worm | Unknown | 65 |
| **Arctidae** | | | |
| *Syntomis Alicia* Butler | Tomato tiger moth | Unknown | 65 |
| **Acarina** | | | |
| Tetranychidae | | | |
| *Tetranychus cinnabrinus* (Boisduval) | Red spider mites | Unknown | 65 |

F = Ferdu Azerefegne, unpublished.

## Sweet potato weevil

The sweet potato weevil was reported to be found in all Woredas surveyed in southern Ethiopia; although there were differences in the extent of stem and tubers damage and weevil population density per plant parts (Ashebir, 2006). High levels of stem and tuber damage and high number of larvae per tuber was recorded in Goffa Zuria, Arba Minch Zuria Woredas (Ashebir, 2006), Nazareth, Werer (Emana, 1987), Awassa, Areka, (Emana and Amanuel, 1992; Adhanom and Tesfaye, 1994) and Humbo (Tesfaye, 2003).

## Basic studies

The biology of sweet potato weevil was studied in Awassa and Nazareth Research Centers. The weevil required 30 and 31.5 days to complete its life cycle in Awassa and Nazareth, respectively. It was also reported that the weevil could complete nine generations at Awassa and eight at Nazareth (Emana, 1987; Emana and Amanuel, 1992).

## Extent of infestation and loss by sweet potato weevil

Loss assessment experiments conducted between 1984 and 1987 at Nazareth and Werer using various insecticides showed that sweet potato weevil can cause losses of 10-48% (Emana, 1987). The bitterness resulting from sweet potato weevil damage makes even partially damaged tubers unsuitable for human consumption. Because of poor storage technology and planting material preservation, farmers practice piecemeal harvesting which keeps the crop in the field for up to six months. Emana (1990) reported increase in infestation by the weevils from 29% to 68% when harvesting was delayed from five to six months. Moreover, growing sweet potato on the same plot of land for four consecutive

years at Awassa resulted in over 70% tuber infestation; whereas under less than 20% infestation was recorded in plots where rotation of crops was practiced (Emana, 1990). The extent of yield loss was high towards the dry season due to low soil moisture, low biomass yield and possibly high soil crack (Ashebir, 2006). The pest is particularly serious under dry conditions because the insect reach the root more easily through the cracks that appear as the soil dries out; therefore, sweet potato root cannot be stored safely in-the ground for long period during the dry season.

### Farmers perception on sweet potato weevils

Ashebir (2006) conducted surveys on farmers' perception in major sweet potato growing areas of southern Ethiopia including Arba Minch Zuria, Goffa Zuria, Bolos Sore, Humbo, Dermot Gale, Sodom Zuria, and Kasha Biro in 2005, and found that insect pests were the major constraints of sweet potato production followed by porcupine, mole rat, shortage of land, drought and storage problem in that order. Among insect pests, 63.8% of the farmers perceived sweet potato weevil to be the most important, while 27.6% of the farmers indicated that sweet potato butterfly is important. The rest of the farmers (8.6%) reported leaf miner and vine borer are important. It was observed that the weevil was important in Humbo, Bolos Sore, Goffa and Arba Minch Zuria Woredas, while sweet potato butterfly was important in Damot Gale and Sodo Zuria Woredas. Leaf miner and vine borer were important in Kacha Bira Woreda. The response of farmers suggested that the sweet potato weevil is more important in the lowland and mid-highland areas, while the sweet potato butterfly, leaf miner and vine borer are important in the mid-highland and highland areas.

The majority of farmers (73.3%) recognized the grubs, while about half of them (53.3%) were found to be acquainted with the adult weevil. The recognition of the larvae by many farmers is understandable as it is the stage of the insect encountered in the tubers during harvesting and utilization (Ashebir, 2006).

## Control measures

### Cultural control

Effect of sowing dates on sweet potato weevil infestation was evaluated at the Awassa and Areka Research Centres in the 1994 cropping season (Adhanom and Tesfaye, 1994). Among the six planting dates extending from June to September, higher tuber infestation was obtained from the late plantings. The highest tuber attack (over 64%) and the lowest yield was obtained from September planted sweet potato followed by the early and late August plantings at Areka (Table

12). The second planting date July 10 gave the highest yield with low weevil infestation. Similarly, higher levels of tuber infestation were recorded from September planting followed by the early and last week of August at Awassa (Table 12). In general, late-planted sweet potato sustained high levels of sweet potato weevil damage at both locations. A similar study conducted in Wolaita indicated that sweet potato planted in August sustained lesser damage than September planted ones (Tesfaye, 2003). Earthling up of soil around the plant three times at monthly intervals starting from the second month after planting significantly reduced infestation of tuberous roots and this practice could enable to delay harvesting for more than six months (Emana, 1990).

Table 12. Effect of sowing date on sweet potato tuber infestation due to sweet potato weevil at Areka and Awassa (after Adhanom and Tesfaye, 1994).

| **Areka** | | | **Awassa** | | |
|---|---|---|---|---|---|
| **Planting date** | **Yield ton/ha** | **Infestation (%)** | **Planting date** | **Yield ton/ha** | **Infestation (%)** |
| June 25 | 6.7 | 0.57 | June 19 | 17.3 | 18.96 |
| July 10 | 14.8 | 0.54 | July 1 | 17.1 | 45.51 |
| July 24 | 4.3 | 8.40 | July 16 | 16.7 | 62.87 |
| August 8 | 12.2 | 28.46 | August2 | 20.1 | 81.12 |
| August 22 | 10.2 | 23.32 | August 16 | 9.9 | 70.76 |
| September 6 | 4.8 | 64.02 | September 3 | 8.1 | 87.03 |
| CV% | 22.6 | 21.10 | CV% | 11.70 | 23.30 |
| $LSD_{0.05}$ | 3.93 | 8.29 | $LSD_{0.05}$ | 3.41 | 25.85 |
| $LSD_{0.01}$ | 1.59 | 11.79 | $LSD_{0.05}$ | 4.85 | 36.76 |

## Varietal resistance

Several researchers have verified the presence of variability in sweet potato genotypes for resistance to sweet potato weevil. However, some of the materials reported to be resistant succumb under high weevil population pressure. Emana (1990) evaluated sweet potato varieties for resistance to the weevil from 1987-1989 and found that 38% of the varieties to be resistant and the remaining were moderately resistant at Areka. At Awassa, however, 55% of the varieties were reported to be moderately resistant and the rest were susceptible. The reason for the variation in the level of resistance at the two locations was attributed to the difference in population density of the pest. Fields at Areka had been cultivated for only three years with sweet potato when the trial was conducted and the pest has not yet established itself. At Awassa sweet potato is repeatedly cultivated for more than a decade in the same field. Some of the varieties like Arba Minch I and II, which seemed to be resistant at Areka, were susceptible at Awassa. However, the low level of infestation at Areka could not be enough to label a variety was resistant or not. Tesfaye (2002) found all of the varieties he tested were damaged by the sweet potato weevil and there was no resistant variety. However, the varieties differed in the degree of damages and infestation levels

they sustained. Varieties Koka 26 and Cemsa had the lowest level of infestation and adult weevil density in the field. On the other hand, varieties TIB-1102 and TIB-1-1102 had higher levels of tuber infestations. It is known that varieties with deeper roots suffer less from the attack of sweet potato weevils. The study also showed that Koka 26 and Cemsa had deeper roots than the other varieties considered (Addis and Tesfaye, 1995b).

## Chemical control

Emana and Adhanom (1990) evaluated seven insecticides as dipping, foliar sprays and combination of both at Awassa and Areka during the 1987 and 1989 cropping seasons. Spraying began two months after planting and continued up to the fourth month at fortnightly interval. Of the seven insecticides, cypermethrin and pirimiphos-methyl gave best control of the sweet potato weevil which resulted in higher marketable yield (Table 13). In another study, dipping of sweet potato vines used for planting in diazinon 60% E.C improved the yield of sweet potato and reduced the level of weevil infestation (Tesfaye, 2002).

Table 13. Efficacy of insecticides in the control of sweet potato weevil (Emana and Adhanom, 1990).

| Insecticide | Areka | | Awassa | |
|---|---|---|---|---|
| | Infestation (%) | Marketable yield (t/ha) | Infestation (%) | Marketable yield (t/ha) |
| Carbaryl | 29.94ab | 7.9cd | 46.3b | 4.4a |
| Cypermethrin | 23.94a | 16.5a | 36.6a | 5.3a |
| Endosulfan | 28.01ab | 8.2d | 44.48b | 5.6.7a |
| Primiphos methyl | 25.01a | 13.4abc | 32.46a | 5.7a |
| Karate | 33.01ab | 8.4cd | 50.67b | 4.5ab |
| Deltamethrin | 23.54ab | 11.1bc | 48.63b | 4.4ab |
| Diazinon-dipping | 28.56ab | 6.8d | 53.73b | 4.7ab |
| Diazinon-dipping + spray | 31.28ab | 9.0cd | 48.06b | 3.8ab |
| Diazinon spray | 31.61ab | 6.6d | 48.13b | 3.6ab |
| Untreated check | 41.13b | 5.1d | 53.14b | 1.3ab |

Means followed by the same letter(s) within a column are not significantly different from each other at 5% level of probability (DMRT).

## Integrated management of sweet potato weevil

The integration of insecticides, early planting and earthling up three times starting from one month after planting highly reduced the percentage of infestation by the sweet potato weevil and increased root yield of sweet potato (Messele *et al.,* 2005).

### Sweet potato butterfly (*Acraea acerata*)

Sweet potato butterfly has become the most important insect pest of sweet potato in the southern parts of the country (Adhanom and Emana, 1987; Emana and Adhanom, 1989; Emana and Amanuel, 1992; Ejigu, 1995; Tesfaye, 1995; Azerefegne, 1999). It was first noted and reported in 1986 as an outbreak in Gamo Goffa Awraja. Since then it has spread over wide areas of southern Ethiopia (Table 14). It poses a very serious threat to the farmers whose daily diet depends on sweet potato. Complete crop failure is now very common in many areas of the region where sweet potato is intensively cultivated.

Table 14. Status of sweet potato butterfly in some localities of southern Ethiopia (after Emana and Amanuel, 1992).

| Survey locations | Status of the pest in different seasons | | |
|---|---|---|---|
| | **1987** | **1990** | **1991** |
| Damot Galle | unknown | major | major |
| Sodo Zuria | unknown | major | major |
| Areka | unknown | minor | major |
| Badessa | unknown | minor | major |
| Gasuba | unknown | unknown | minor |
| Selamber | minor | major | major |
| Sawla | major | major | major |
| Chanodorga | major | minor | absent |
| Zefine | minor | minor | absent |
| Wajifo | minor | absent | absent |

# Basic studies

### Biology of the sweet potato butterfly

Azerefegne (1999) studied the biology of sweet potato butterfly in southern Ethiopia and found that the insect breeds throughout the year with about six discrete generations a year. Females lay their eggs in single layered batches of approximately 160 eggs on the underside of young as well as old sweet potato plants. Most eggs were found on the middle leaves along the vine. Larvae passed through five instars; the first three instars were found to feed gregariously whereas the last two instars dispersed and feed solitarily. Larval development was shorter in males than in females. Pupation took place on the foliage or on the ground. Pupation under clods of soil and in cracks was more frequent during the dry periods. The pupal stage lasted about seven days and adults emerged during the daytime, while mating occurred during afternoons. The adults lived for a short time with a maximum life span of nine days. In the laboratory, total development from egg to adult took 34 days. However, in the field both egg and larval developments were of longer durations resulting in a total development

time of 40-50 days from egg to adult. Moreover, larval development was extended by 10 days during the rainy period compared with the dry periods. Adult butterflies are aposomatically coloured with orange and black. There is a less bright colour form which was frequent at all times of the year. Both male and female butterflies were found to feed on flowers of many plants such as *Bidens pilosa, Croton macrostachys, Tagetes minuta, Guizota scabra* and *Solanum tuberosum*.

## Host plants of sweet potato butterfly

The association between the sweet potato butterfly and sweet potato is relatively new because sweet potato originated from or near north-western America (Austin, 1988). The plant was introduced to Africa about 500 years ago by European explorers (Yen, 1982). But the butterfly is indigenous to Ethiopia where it feeds on native plants. Larvae have been reported to feed on *I. tenuirostris* Choisy., *I. lilacina* Blume, *I. kentrocarpa* A. Rich., *I. wighiti* Choisy., and *Lepistimone owariense* Hall., all in the family Convolvulaceae (Lefévre, 1948; Matanmi and Hassan,1987; Smit, *et al*., 1997; Subukino, 1997). Claims that larval food plants include Poaceae, Cucuribitaceae and Solanaceae (Larsen, 1991) are suspect because larvae have never been observed feeding on any other species than *Ipomoea* even at times of high population density and food limitation in Ethiopia (Azerefegne, 1999). Larvae of the sweet potato butterfly develop not only on sweet potato but also on various wild *Ipomoea* species in Ethiopia. Larvae fed and developed successfully on two indigenous species, *I. cairica* and *I. tenuirostris*, whereas larvae refused to feed on the abundant indigenous *I. hochstetteri*. Introduced species, *I. indica* and *I. purpurea* were unsuitable for development; larvae refused to feed on the former species and had extremely low survival rates on the latter one. *I. batatas* was a better host plant than both *I. cairica* and *I. tenuirostris*; larvae survived well and pupae were larger and females contained high number of mature eggs resulting in more fecund female butterflies. However, there was no difference between larvae developed on *I. cairica* and *I. tenuirostris*. Nevertheless, in southern Ethiopia, wild populations of the insect were not found on *I. cairica* but only on *I. tenuirostris* and *I. obscura*, a plant on which larval performance was not tested (Azerefegne, 1999).

## Natural enemies of sweet potato butterfly

The larva of the sweet potato butterfly is attacked by three parasitoid species viz *Glyptapanteles acraeae* (Wilkinson) (Braconidae), *Charops* species (Ichneumonidae), and *Carcelia* sp. (Tachinidae), and the pathogenic fungus *Beauveria bassiana* (Balsamo) Vuillemin (Moniliaceae), whereas pupae are parasitized by *Brachymeria albicrus* (Klug) (Chalcidoidea) (Azerefegne, 1999). *Charops* sp. was also reported from earlier studies (Emana and Adhanom, 1989;

IAR, 1988; 1989). The enemies generally seem to be of little importance in reducing high density host populations (Azerefegne, 2000). At low population levels, however, enemy effects sometimes increase, possibly causing longer and deeper population valleys. *Glyptapanteles acraeae* attacks the young host larva. The host is usually killed (87.8%) in the fourth instar. *Charops* sp. attacked during the second larval instar of the pest and emerged somewhat later than *G. acraeae*, mainly (82.9%) from the fifth instar host larvae. *Carcelia* sp. was found to attack older larvae than the two previously mentioned parasitoids. Some *Carcelia* sp. emerged from the last instar host larvae, but the majority (67.7%) emerged from host pupae. *Brachymeria albicrus* appeared to oviposite only in the pupa of the butterfly as it was never retrieved from rearing of field collected larvae. It also emerged from host pupae. Population densities of *G. acraeae* and *Charops* sp. were low during the entire study period. Mortalities caused by *G. acraeae* never exceeded 6% of young larvae, and *Charops* inflicted mortalities not more than 12% of old larvae (Azerefegne, 1999). Mortalities inflicted on the host population increased briefly when host population density was very low. No direct density dependent effects could be found for these two parasitoid species. *G. acraeae* even showed a weak inverse density dependent effect.

Butterfly larvae infected by the pathogenic fungus *Beauveria bassiana* usually died during the last two instars. The incidence of *B. bassiana* infections was low during most of the time. No density dependent effects of *Beauveria* could be discerned. The combined mortalities of *G. acraeae*, *Charops* sp. and *B. bassiana* did not show a significant density dependent response when regressed against log density of young larvae (Azerefegne, 2000). In a sample of 838 pupae collected over several days during a peak host population period of a generation, 4.1% were killed by emerging *B. albicrus* and 6.7% by *Carcelia* sp. (Azerefegne, 1999).

## Generation and population fluctuation

The *A. acerata* population developed with discrete and easily discerned generations, so called generation cycles (Azerefegne, 1999). A total of 21 butterfly generations were observed during three and a half years (October 18, 1994 - April 23, 1998), which means about six generations per year (Fig. 14). There were large variations in population density between generations and years. Generation peaks were relatively high from late 1994 until August 1996 after which density decreased drastically and remained low for about one year.

Looking at generation totals (Fig. 15) the ranges of population fluctuations were over four orders of magnitude. The net reproductive rate usually varied within the range of 0.1-10 (Fig. 16). The population change was thus gradual and there were long periods (up to five generations) of either continuous growth or decline.

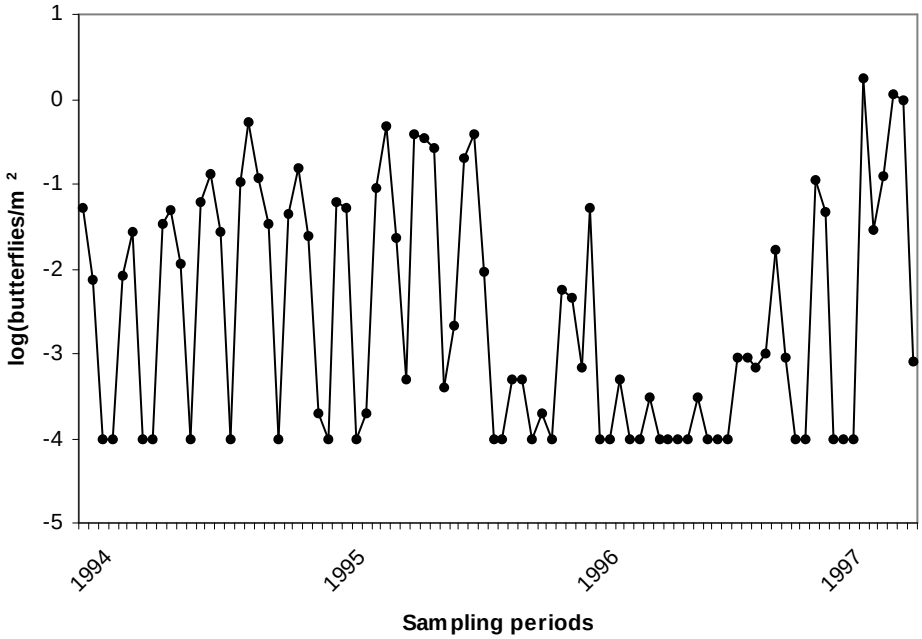


Fig. 14. Population fluctuation of *Acraea acerata* at 15 day interval from December 1994 to April 1998 (Azerefegne, 1999).

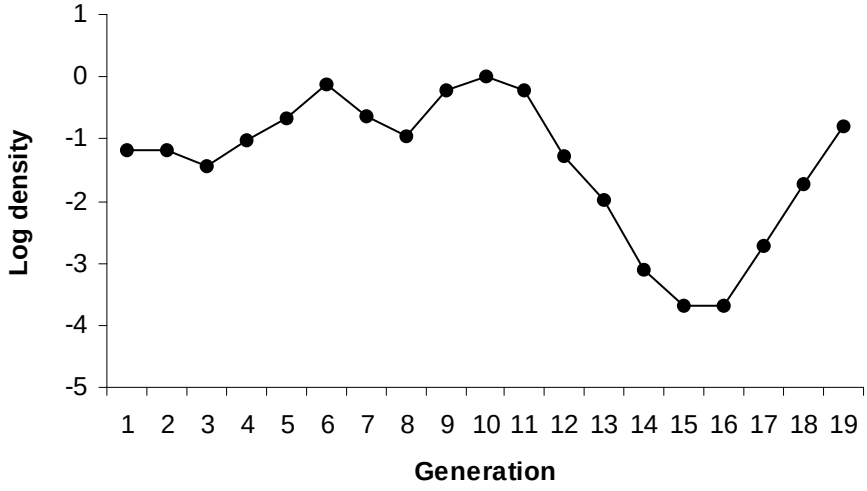


Fig. 15. Generation totals of *Acraea acerata* butterflies (Azerefegne, 2000).

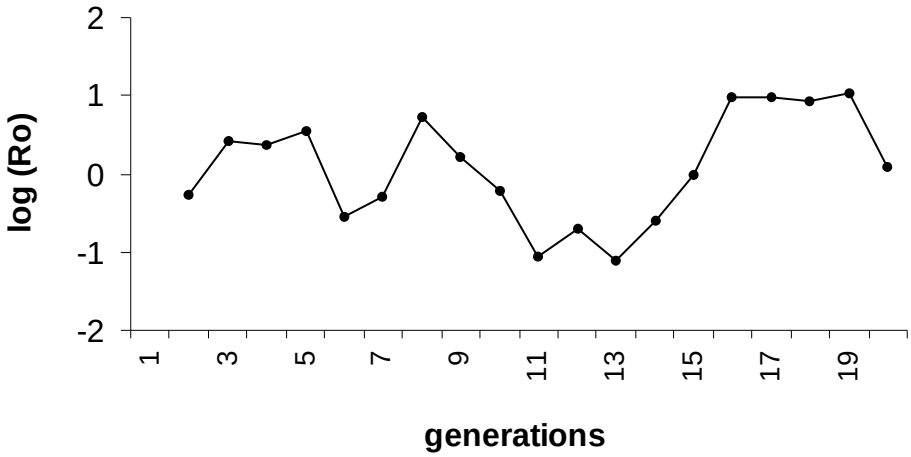


Fig. 16. The net reproductive rate of *Acraea acerata* (Azerefegne, 2000).

## Extent of infestation and yield loss

Two peaks of larval density were observed during the five to six month cropping cycle representing two successive insect generations (Azerefegne, 1999). The insect population density varied between the three growing seasons studied. High densities were observed during the 1995/96 (Fig. 17a) and 1997/98 (Fig. 17c, d) cropping seasons, with 7-10 and 6-12 larval tents per square meter, respectively, in the first generation. The 1996/97 season had the lowest number of larvae when compared with the other seasons (< 0.1 larval tents/$m^2$ at any time) (Fig. 17b).

During the 1995/96 season larvae feeding caused considerable leaf damage as well as reduction in ground cover (Fig. 17a). The difference in the ground cover between the protected and unprotected plots reached a maximum of 28%. While the protected plots reached 100% ground coverage, the unprotected plots did not surpass 90%. About 80% of the leaves on the unprotected plots showed signs of sweet potato butterfly larvae feeding damage.

In the 1996/97 cropping season, there were very few larvae (Fig. 17b) and no differences in ground cover were observed between the sprayed and unsprayed plots. Unlike the other two periods studied, the 1996/97 cropping season was not favourable for growth of sweet potato because of a prolonged dry period. In consequence, complete coverage of the ground was never attained at any time during the growing period.

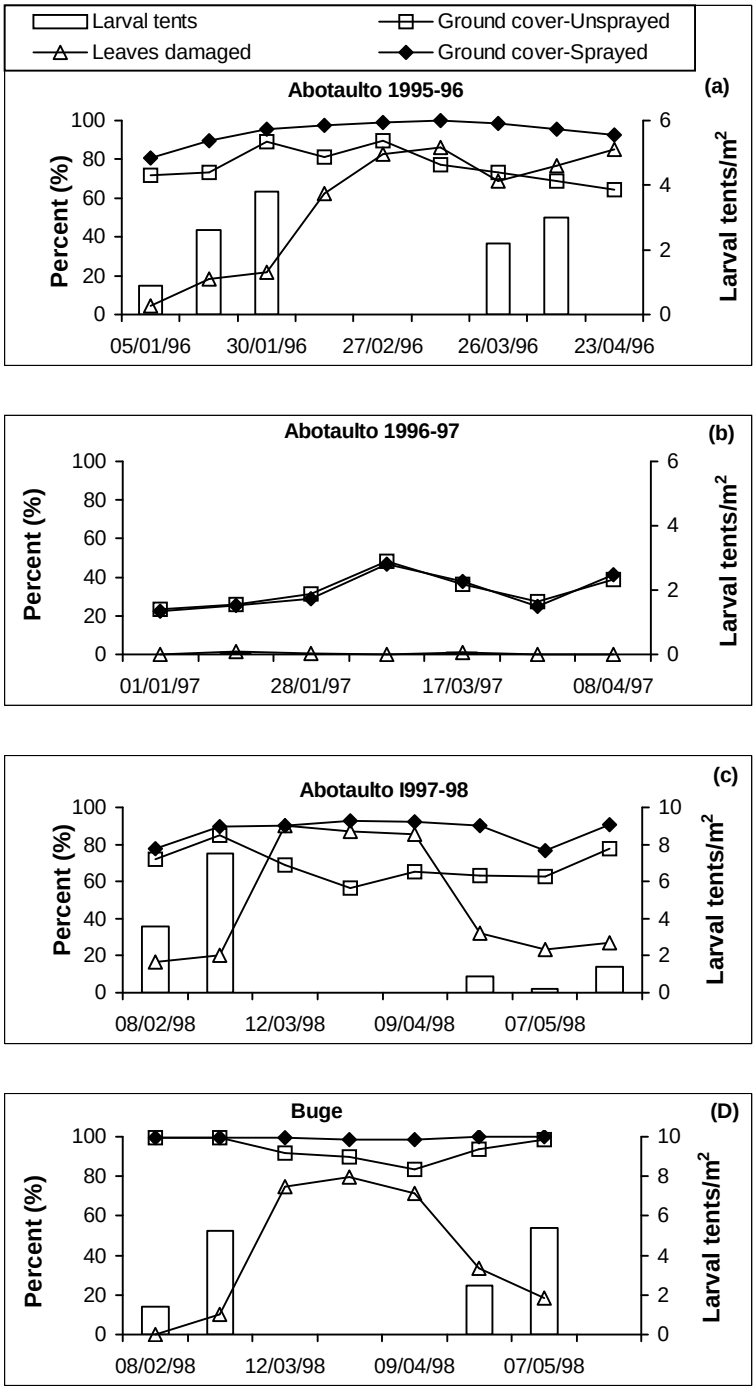


Fig. 17. *A. acerata* larvae density and damage on sweet potato.

In the 1997/98 season, reduction of the ground cover was observed on the unprotected plots compared with protected ones (Fig.17c, d). The reduction ranged from 14 to 53% at the different farms. The proportion of leaves infested ranged from 79-90%.

There was a considerable variation between seasons and locations in crop yield (Table 15). Yield ranges of 5-28 t/ha for five-month harvests and 8-35 t/ha for six month harvests were recorded from the different farms. In the 1995/96 and 1997/98 cropping seasons, the protected plots produced significantly more tuberous roots (Table 15). This significant difference was observed for both five and six month harvests. In the 1996/97, there was no infestation by the insect and thus there was no difference between the sprayed and unsprayed plots. The yield was lower than in the other years of the study due to drought.

Root yield loss of both early and late harvests was strongly correlated with the density of larvae during the first generation (Fig. 18a), explaining about 76 and 66% of the yield reduction in early and late harvests, respectively. The yield loss was not significantly correlated with total larvae density of both generations (Fig. 18b).

The estimated cost of spraying a hectare of land twice during the growing period (316 Eth. birr) showed that there should be a difference of 1.05 t/ha to make insecticide treatments economically profitable. The price of sweet potato at the nearest market was very low (30 birr/100 kg). Nevertheless, the use of insecticides was economically justifiable in all cases of high insect density. The profits ranged from 1119-2669 birr for early harvests and 1684-3126 birr for late harvests. The profit was higher for late harvests (Table 15).

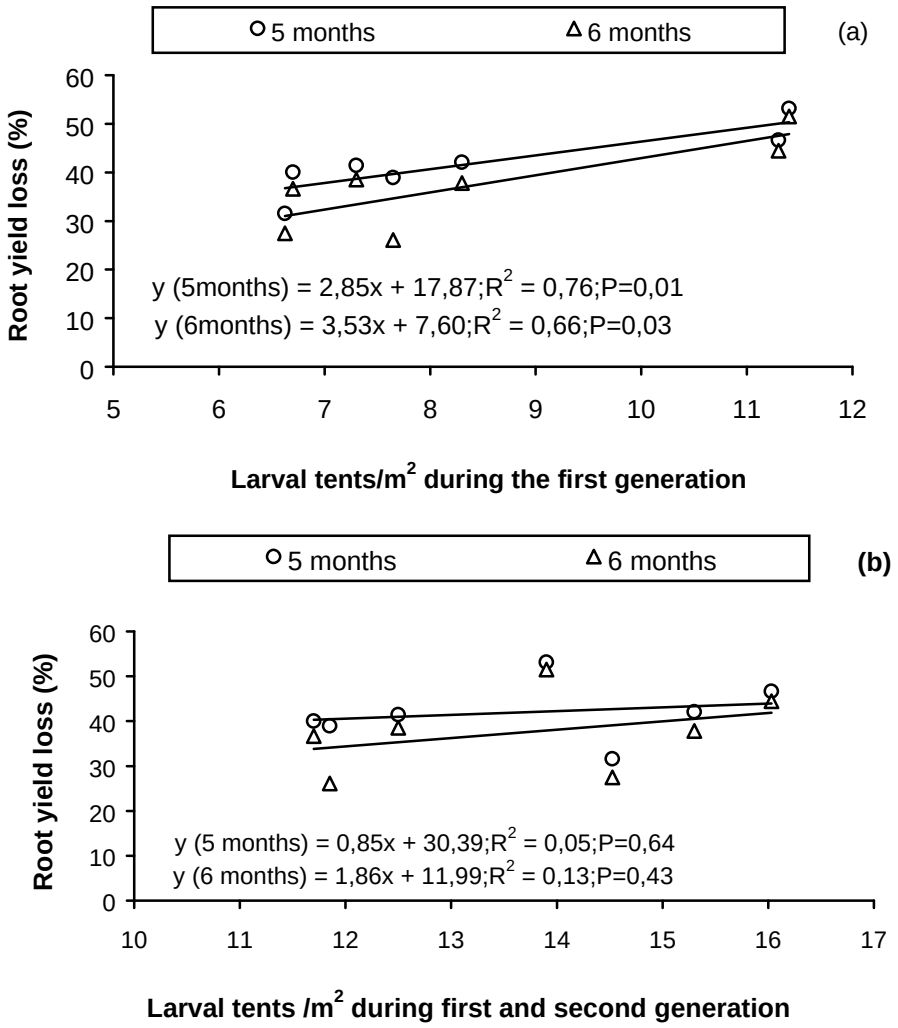


Fig. 18. Relationship between larval density of *Acraea acerata* during a) first generation and b) first and second generation, and tuberous root yield loss (Azerefegne, 1999).

## Control of sweet potato butterfly

According to Ashebir (2006), more than 75% of the interviewed farmers in Wolaita did not use any control measure against the sweet potato butterfly, and less than 28% of the farmers applied control methods such as manure, wood ash, irrigation, mulching and a synthetic insecticide (malathion).

Table 15. Yield loss of sweet potato in farmers' fields caused by *A. acerata* (after Azerefegne, 1999).

| Season | Location | Treatment | 5 months | | | 6 months | | |
|---|---|---|---|---|---|---|---|---|
| | | | Tuberous root yield (t/ha) | Loss (%) | Profit (birr) | Tuberous yield (t/ha) | Loss (%) | Profit (birr) |
| 1995-96 | Abotaulto | unsprayed<br>sprayed | 16.86a<br>28.78b | 41.4 | 2669 | 21.97a<br>35.74b | 38.6 | 3126 |
| 1996-97 | Abotaulto | unsprayed<br>sprayed | 7.61a<br>7.35a | - | - | 9.03a<br>8.85a | - | - |
| 1997-98 | Abotaulto-I | unsprayed<br>sprayed | 5.21a<br>11.12b | 53.2 | 1161 | 8.28a<br>17.09b | 51.5 | 1885 |
| | Buge | unsprayed<br>sprayed | 12.44a<br>18.18b | 31.6 | 1119 | 17.60a<br>24.26b | 27.5 | 1684 |

In comparison between sprayed and unsprayed treatments at each site means followed by same letter are not significantly different from each other.

## Host plant resistance

Tesfaye (1995) tested six sweet potato cultivars for resistance in terms of preference of adults for oviposition, landing and visiting as well as the level of larval infestation. However, no variation was observed among the varieties evaluated.

## Use of botanicals

Mesele et al. (2004) evaluated leaf and seed extracts of *Tephrosia vogelli*, *Datura stramonium*, *Mellia azadirachta*, *Chenopodium album* and *Milleitia ferrugenia*, and leaf of *Calusia abyssinica* and seed of *Azadirchta indica* for their insecticidal activity against the sweet potato butterfly larvae, and found that the botanicals showed differential insecticidal activity with respect to larval mortality and damage to sweet potato. *M. ferrugenia*, *T. vogelli* and *A. indica* out performed in killing sweet potato butterfly larvae and influenced larval leaf feeding compared to the other botanicals considered (Table 16). Farmers in Wolaita area try different botanicals to control the sweet potato butterfly. There are reports that they make water suspension of crushed fruits of *Solanum incanum* (Embuaye) and sisal leaves and sprinkle over the infested plants with water. However, detailed studies on the level of control are lacking (Ejigu, 1995).

In another study, the efficacy of *Milletia ferrugenia* seed powder aqueous suspensions was evaluated against the sweet potato butterfly larvae under the laboratory and field conditions (Azerefegne, 2006). Dipping tests conducted in

the laboratory showed that *M. ferrugenia* can cause high level of mortality on the fourth and fifth instar larvae. Sprays of 5 and 10% of *M. ferrugenia* on the larvae under filed conditions caused more than 90% mortality and there were very few survivors. Survival of the larvae was higher at Sodo zuria where most of the larvae had entered the fifth instar. The result indicated that sprays should be timed at earlier instars of the insect.

## Chemical control

Tesfaye (1995) reported that cypermethrin, carbaryl, deltamethrin, diazinon, endosulfan, lamdacyhalothrin and malathion gave satisfactory control when applied at the manufacturers' rates. Addis and Tesfaye (1995) also reported that pirimiphos-methyl, diazinon, carbaryl, deltamethrin and endosulfan were effective against the sweet potato butterfly.

Table 16. Effects of botanicals on percentage morality of sweet potato butterfly larvae and percentage leaf damage of sweet potato (after Mesele *et al*., 2004).

| Treatments | Part used | Days after treatment application (DAT) | | | | Damaged leaves (%) |
|---|---|---|---|---|---|---|
| | | 1 | 5 | 10 | 15 | |
| *Tephrosia vogelli* | seed | 60bc(7.54) | 26.7ab(4.48) | 6.67b(1.98) | 0a(0.71) | 4.6 c (1.58) |
| *T. vogelli* | leaf | 33.3cd(4.95) | 46.7a(6.84) | 13.3b(2.59 | 6.7a(1.98 | 1.5c(1.32) |
| *Datura stramonium* | seed | 6.7 de(1.98) | 6.7bc(1.98) | 0b(0.71) | 0a(0.71) | 17.2b(4.21) |
| *D. stramonium* | leaf | 13.3 e(3.72) | 0c(0.71) | 0b(0.71) | 6.7a(1.98) | 13.2b(3.82) |
| *Calusia abysinica* | leaf | 13.3de(3.72) | 6.7bc(1.98) | 0b(0.71) | 0a(0.71) | 13.4b(3.71) |
| *Azadrichta indica* | seed | 6.7 de(1.98) | 26.7ab(5.21) | 40a(6.22) | 0a(0.71) | 4.2c(2.16) |
| *Mellia azadirach* | leaf | 0e(0.71) | 20 bc(4.53) | 6.7b(1.98) | 0a(0.71) | 12.4b(3.51) |
| *Chenopodium album* | leaf | 6.7 de(1.98) | 6.7bc(1.98) | 6.7b(1.98) | 0a(0.71) | 16.8b(4.16) |
| *Milletia ferrugenia* | seed | 80 ab(8.97) | 20bc(4.53) | 0b(0.71) | 0a(0.71) | 2.2c(1.52) |
| *M. ferrugenia* | leaf | 66.7b(8.12) | 6.7bc(1.98) | 0b(0.71) | 0a(0.71) | 1.9c(1.45) |
| Endosulfan E.C | - | 100a(10.02) | 0c(0.71) | 0b(0.71) | 0a(0.71) | 1.2c(1.16) |
| Untreated | - | 0e(0.71) | 0c(0.71) | 0b(0.71) | 0a(0.71) | 26.6a(5.20) |

Means followed by the same letter (s) within a column are not significantly different at ($P<0.05$)
Figures within brackets are square root transformed values.

Table 17. Efficacy of insecticides in the control of sweet potato butterfly.

| Insecticide treatments | Rate (g a.i./ha) | Infestation (%) | Yield (t/ha) |
|---|---|---|---|
| Endosulfan 35% EC | 700 | 29.68a | 19.5 |
| Deltamethrin 2.5% E.C. | 12.5 | 30.80ab | 14.6 |
| Primiphos-methyl 50% E.C | 500 | 32.60ab | 13.7 |
| Diazinon 60% E.C | 1 (litre) | 37.00abc | 12.9 |
| Carbaryl 25%WP | 1500 | 35.00ab | 12.5 |
| Lambda cyhalothrin 5% E.C | 12.5 | 37.00abc | 11.3 |
| Untreated check | - | 44.40c | 9.9 |
| CV% | | 15.39 | |

Source: Tesfaye, 1995

Means followed by the same letter(s) within a column are not significantly different from each other at 5% (DMRT).

## Insect pests attacking yam and cassava

There are a few records of insect pests on yam (Table 18). Scale insects are reported to cause heavy damage on cassava in Amaro area, southern Ethiopia. However, not much work has been done to date.

Table 18. Insect pests of yam recorded in Ethiopia (after Tsedeke, 1988).

| Scientific name | Common name | Status |
|---|---|---|
| **Homoptera** | | |
| **Cicadellidae** | | |
| *Empoasca barbistyla* Paoli | Yam leaf hopper | unknown |
| *Poecilocarda nigrinervis* Stal | black stripped jassid | unknown |
| **Margarodidae** | | |
| *Icerya purchasi* Maskell | Cottony cushion scale | unknown |
| **Coleoptera** | | |
| **Chrysomelidae** | | |
| *Lilioceris livids* (Dalman) | Yam beetle | unknown |

# Conclusion and recommendations

On potato PTM is the most important insect pest in the field and storage. Application of pyrethrum flower powder on stored tubers reduced the damage by PTM. The synthetic insecticide diazinon 60% EC effectively controlled the pest in the field.

Enset root mealybug can be controlled by use of free enset plants. It is important to teach farmers that the chief means of distribution is through planting

materials. They should be advised to avoid seedlings coming from infested areas. Some farmers plant seedlings from highlands where infestation is expected to be low. Addition of farmyard manure supports enset plants to grow and develop better and withstand damage by the enset root mealybug, but will not completely eradicate it. Studies are going on on the use of hot water treatment to produce mealybug free planting materials. *M. ferruginea* seed-water suspensions is toxic to enset root mealybugs and caused about 66% mortality in pot experiments. However, one application of *Milletia* cannot satisfactorily control the insect. Two applications of *M. ferruginea* improved its efficacy and raised the level of mealybug mortality to about 79%. Combinations of dipping young enset seedlings and repeatedly drenching of the root zone of infested enset plants with the *Milletia* seed water suspension may be used as part of IPM for the enset root mealybug. The synthetic insecticides chlorpyrifos and diazinon are effective against enset root mealybugs when the root zone of infested enset is drenched with the suspensions of the insecticides.

In southern Ethiopia, sweet potato is grown year round and plots of different ages are always found in a farm. Sweet potato plots belonging to the same farmers or neighbours are located immediately next to the older plots or within 10 m distance, which create conducive conditions for the continuous infestation by the sweet potato weevil. Therefore, neighbouring infested sweet potato fields and leftover infested sweet potato tubers are the most important sources of infestation for newly planted sweet potato plots in the region. Good field sanitation and planting away from weevil-infested fields are the two practices expected to have noticeable effect on weevil management. Farmers of the region are not familiar with the life cycle and dispersal of the sweet potato weevil. They do not usually establish the link between the mobile adult weevil and larva. Therefore, acquainting farmers to the sweet potato weevil life cycle will help in the extension of cultural control methods. The carryover effect of the weevil from an infested crop to a new field can be reduced by careful selection of planting materials by taking the tip of the vine. Vine tip planting is recommended because it produces high yield, and it is likely to be free from prior infestation by the pest. Sweet potato planting at different times of the year encountered varying levels of infestations by the weevil. Therefore, planting at the appropriate time minimizes infestation. Generally, for sweet potato plantings of June to September, the main rainy season, early planting is advised. Those planted late need to be protected with insecticides. There are no resistant varieties for the sweet potato weevil. However, varieties differed in the degree of damage and infestation by the pest. For example, varieties Koka 26 and Cemsa which are characterised by deeper roots had the lowest level of infestations and adult weevil density in the field. Among the insecticides, cypermethrin, pirimiphos-methyl, and diazinon were found to be effective against the weevil.

To get better result farmers should integrate planting less susceptible varieties, use of vines free from infestation by dipping vines in insecticides or using the tip part only, early planting, earthling up three times starting from one month after planting, and insecticide spraying if the area experiences high level of infestations.

Among the botanicals tested, *M. ferrugenia, T. vogelli* and *A. indica* were found to be effective and can be used for the managment of the sweet potato butterfly. On the other hand, the insecticides cypermethrin, carbaryl, deltamethrin, diazinon, endosulfan, lambdacyhalothrin, malathion and pirimiphos-methyl gave satisfactory control when applied at the manufacturers' rates. These insecticides can be used during outbreak periods.

## Gaps and challenges

The studies of root and tuber crop pests focused on very important few insects. Most of the studies did not continue for longer durations and similar types of non-detailed studies prevailed in most of the cases. Long term studies encompassing different generations and seasons are lacking. The status of pests of these crops is not known except for those which cause significant crop damage. Research on combination of control methods with the attempt to develop IPM is very few. In addition, economic feasibility of the control methods recommended is not well worked out and the infestation levels, which warrant the use of control measures, are not given. During the period between 1992 and 2003, research activities carried out on potato entomology were limited; comprehensive surveys of insect pests on potato were not conducted. For example, studies on species composition of aphids attacking potato, their distribution and transmission of virus diseases are scarce. From the limited number of studies conducted on potato it can be concluded that there was no new record of insect pests on potato. There are very few recommendations for the management of PTM.

The sweet potato weevil is relatively better studied among the tuber and root crop pests and effort has been made to develop management practices including use of appropriate varieties, insecticides, botanicals, and cultural practices. However, the studies on planting dates and insecticide evaluations are very repetitive. The study on the effect of planting period of sweet potato on the damage by the sweet potato weevil does not cover all the planting periods of sweet potato. Most of the studies compared planting dates conducted from July to October, However, farmers in southern Ethiopia plant sweet potato throughout the year if soil moisture is not limiting.

Sweet potato butterfly has been one of the pests which got research attention. The studies have shown that it can be controlled by some selected botanicals and

insecticides. The temporal distribution of the insect is one of the areas which need investigation. Evaluations of insecticides and botanicals were conducted at high population density of the insect. The botanicals recommended are based on laboratory and small-scale field studies. The insecticide recommendations usually did not indicate the volume of spray and economic analyses are not included.

Studies on the enset root mealybug have just started. The effects of the pest on the growth and development of enset, the reaction of the various cultivars of enset to the mealybug; the natural enemies and the alternate hosts of the mealybug are not known.

## Prospects

The insects listed as pests of root and tuber crops should be verified and additional data gathered on their distribution and extent of damage. Besides PTM, the red ants have become a consistent menace in the cool highlands of central Ethiopia calling for research attention. The focus of potato entomology should be in developing integrated management strategies to control PTM, the red ant and aphid species vectoring viruses. PTM research should look into the evaluation of new management techniques being used in other countries to give multiple options to users.

Work on sweet potato weevil need to concentrate on cultural practices such as avoidance of adjacent planting of successive sweet potatoes, selection of appropriate barrier crops and appropriate planting dates and practicing field sanitation. Moreover, mulching should be investigated to determine the amount, time and type of mulch materials in relation to weevil control and sweet potato yields. In addition, creating awareness among farmers on the life cycle of the insect and its dispersal is very important.

Techniques of protecting enset planting materials from enset root mealybugs in nurseries and regulating the distribution and exchange of planting materials should be devised. The enset root mealybugs are attended by ants. The association between the ants and the mealybugs, and the role played by ants on the population dynamics of the mealybugs need to be investigated. Emphasis should also be given to those affordable management techniques like cultural methods and use of botanicals.

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# Review of Research on Insect and Mite Pests of Vegetable Crops in Ethiopia

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## Introduction

Different types of leafy, root, bulb and fruit vegetables are grown in different agro-climatic regions of the country under rain-fed and irrigated conditions. The most important ones include tomato, onion, hot pepper and cabbage. Others such as cucurbit, eggplant, okra, lettuce, green beans, etc. are also important. These crops are important components in the diet of the Ethiopian people. They are also sources of employment and income to small-scale farmers. The production of vegetable crops is expanding with the expansion of irrigation scheme. Table 1 shows production statistics of vegetable crops cultivated in Ethiopia.

Table 1. Area coverage and production of vegetable crops in Ethiopia (MOA, 2002).

| **Vegetable crops** | **Area in ha** | **Percent of total area** | **Production (t)** | **Percent of total yield** |
|---|---|---|---|---|
| Lettuce | 235 | 0.18 | - | - |
| Head cabbage* | 2120 | 1.6 | 1520 | 1.7 |
| Ethiopian. Cabbages** | 27143 | 21.0 | 26240 | 29.4 |
| Tomatoes | 2919 | 2.2 | 3610 | 4.04 |
| Green pepper | 4783 | 3.7 | 4420 | 4.9 |
| Red pepper | 56991 | 44.0 | 7240 | 8.1 |
| Swiss Chard | 142 | 0.1 | 60 | 0.06 |
| Beetroot | 1486 | 1.1 | 1640 | 1.83 |
| Carrot | 1741 | 1.3 | 1780 | 1.99 |
| Onion | 17980 | 13.9 | 22960 | 25.7 |
| Garlic | 13657 | 10.5 | 19670 | 22.0 |
| Total | 129197 | 99.58 | 89200 | 99.40 |

**B. oleracea* var capitata, ***(*B. oleracea* var acephala and *B. carinata*

There are many complex production and technical constraints that limit the expansion of the sector in the country. Insect pests are among the major

constraints. Huge amount of losses in different vegetable crops have been recorded by different workers. These include losses of 36-91% due to DBM in cabbage (Ayalew and Abate, 1994; Ayalew, 2006), 26-57% in onion due to thrips (Abate 1983 and Merne, 2005), 30% in tomato due to PTM and ABW (Negasi, 1988) and 11-27% due to ABW in hot pepper (Abate, 1986). Entomological research on vegetable crops in Ethiopia between 1979 and 1984 has been reviewed by Abate (1986). This paper covers progress made since then.

# Research findings

## Insect pests recorded

Abate (1988a) documented insect pests of vegetable crops cultivated in Ethiopia. Although a large number of insect pests are recorded on each crop, only a few of them are reported to be economically important. The insect species and their status on the commonly grown vegetable crops are presented in Appendice 1, 2, 3 and 4.

## Predators and parasitoids

Abate (1991) listed natural enemies of insect pests attacking various groups of crops including horticultural crops, cereals, legumes and stimulants. Specific surveys targeted to determine natural enemy complex were reported only for a limited number of insect pests of few crops. Due to this, the list does not have much information on natural enemies of major pests of vegetable crops. The available information with regard to this is on parasitoids of the whitefly (*Bemisia tabaci*) attacking tomato, the cabbage aphid, *Brevicoryne brassicae* attacking cabbage and predators of thrips (*Thrips tabaci*) attacking onion as shown in Table 2.

Table 2. Parasitoids/predators associated with insect pests of vegetable crops in Ethiopia.

| **Parasitoid/predator** | Pests attacked | Crop | Reference |
|---|---|---|---|
| *Oomyzus sokolowskii* | *Plutella xylostella* | cabbage | 16 |
| *Diadegma* sp. | *P. xylostella* | cabbage | 16 |
| *Apanteles* sp. | *P. xylostella* | cabbage | 16 |
| *Brachchymeria* sp. | *P. xylostella* | cabbage | 16 |
| *Mesopolobus* sp. | *P. xylostella* | cabbage | 16 |
| *Pediobius* sp. | *P. xylostella* | cabbage | 16 |
| *Itoplectis* sp. | *P. xylostella* | cabbage | 16 |
| *Meloboris* sp. | *P.xylostella* | cabbage | 16 |
| *Aphidius* sp. | *Brevicoryne brassicae* | cabbage | 4 |
| *Diaeretiella rapae* | *B. brassicae* | cabbage | 4 |
| *Pachyneuron* sp. | *B. brassicae* | cabbage | 4 |
| *Encarsia formosa* | *Bemisia tabaci* | tomato | 4 |
| *Eretmocerus mundus* | *B. tabaci* | tomato | 4 |
| *Telonomus* spp. | *Helicoverpa armigera* | tomato | 37 |
| *Trichogrammatoidea sp. nr lutea* | *H. armigera* | tomato | 37 |

Table 2. Cont'd.

| **Parasitoid/predator** | Pests attacked | Crop | Reference |
|---|---|---|---|
| *Trichogrammatoidea sp. nr armigera* | *H. armigera* | tomato | 37 |
| *Trichogramma sp. nr. mwanzia* | *H. armigera* | tomato | 37 |
| *Trichogramma sp. nr. bournieri* | *H. armigera* | tomato | 37 |
| *Adonia variegata* | *Thrips tabaci* | onion | 4, 24 |
| *Orius* sp. | *T. tabaci* | onion | 4, 24 |
| *Chrysopa* spp. | *T. tabaci* | onion | 4, 24 |
| *Baccha* spp. | *T. tabaci* | onion | 4, 24 |

Ayalew and Ogol (2006) have given an account on the diversity of the species of parasitoids associated with the diamondback moth and Negri (2004) on the diversity of egg parasitoids associated with African bollworm.

# Basic studies

## Studies on insect biology

### Diamondback moth *(Plutella xylostella)*

The biology of the diamondback moth (DBM) was studied for two generations on four cultivated brassica and one wild crucifer in the laboratory at the Melkassa Research Center in 2002. In the first generation, the fecundity was 140-294 eggs/female, the durations for egg hatching, larval, pupal, and adult longevity ranged from 2.8-3.5, 7.8-9.6, 5.2-5.6, 10.8-12.4 days, respectively. In the second generation, the fecundity was 63-320 eggs/female, and the durations were 2.6-4, 9.2-10.7, 5.7-6.8, 10.4-11.4 days for egg hatching, larval, pupal, and adult longevity, respectively. The life table statistics showed that the head cabbage, *Brassica oleracea* var. *capitata* L., was the most suitable host for the pest with the shortest development period and the highest reproductive potential. Both development period and life table statistics showed that the weed *Erucastrum arabicum* Fisch and Mey was more suitable than some of the cultivated species (Ayalew et al., 2006a). The biology of DBM was also studied at the Plant Protection Research Center (PPRC) at Ambo in 1993/95 at two different temperatures, 19.5$^{o}$C and 23 $^{o}$C. It was reported that the generation time (egg to adult) was 26.9 days at 19.5$^{o}$C and 18.2 days at 23 $^{o}$C (PPRC, 1995).

### Potato tuber moth *(Phthorimaea operculella)*

Mulatu (2003) studied the biology of the potato tuber moth (PTM) on three different tomato types namely cherry, processing and fresh market type at two growth stages (pre-blossom and blossom), and on potato (the primary host for PTM). Significant interactions were found between the crop cultivars and the

two plant phenologies on development time of PTM. The total development period for the larvae at the pre-blossom stage was significantly shorter (18.4 days) on potato, longer (21.5 days) on the processing type and intermediate (20.7 days) on the fresh market and the cherry (20.4 days) types. At the blossom stage, the larval development time was significantly longer (21.0 days) on the cherry and on the fresh market types (22.2 days) and shorter (16.5 days) on potato. The development time for the pupae did not differ significantly among the tomato cultivars and potato at the pre-blossom stage, but was significantly longer (10.9 days) on potato at the blossom stage. Larva-to-adult development at the pre-blossom stage was significantly shorter (29.5 days) on potato than that of the tomatoes (30.7-32.0 days). At the blossom stage, it was longer (28.9 days) on the cherry tomato and shorter (27.4 days) on the potato and on the processing tomato type (27.3 days).

## Studies on population dynamics

### Diamondback moth on cabbage

Changes in the population of DBM and the level of parasitism on head cabbage was monitored for two seasons in two different agro-ecological zones representing the highland and lowland brassica producing areas of central Ethiopia in 2001 and 2002. It was found that two to three generations occur in the highland and three to five generations in the lowland areas (Ayalew et al., 2006b). Rainfall and maximum temperature showed significant influences on the DBM population and the activity of parasitoids in the highland (Fig. 1). An earlier study at Ambo on the seasonal occurrence between 1993 and 1994 showed that the peak DBM population (45/plant) was in October (PPRC, 1995). The population increase was reported to be positively correlated with the maximum temperature and negatively correlated with the rainfall, although both of the relationships were not statistically significant.

### Onion thrips (*Thrips tabaci*) on onion

Previous studies (Abate, 1986) showed that thrips numbers were highest in the hotter parts of the year (February through April), and lowest in the rainy seasons (June through August). Merene (2005) studied the population fluctuation of the onion thrips in 2004 in the northeastern part of the Amhara region, and reported a similar result. The population density of thrips was low during the rainy and cooler months of August to November and high during the months of February to April.

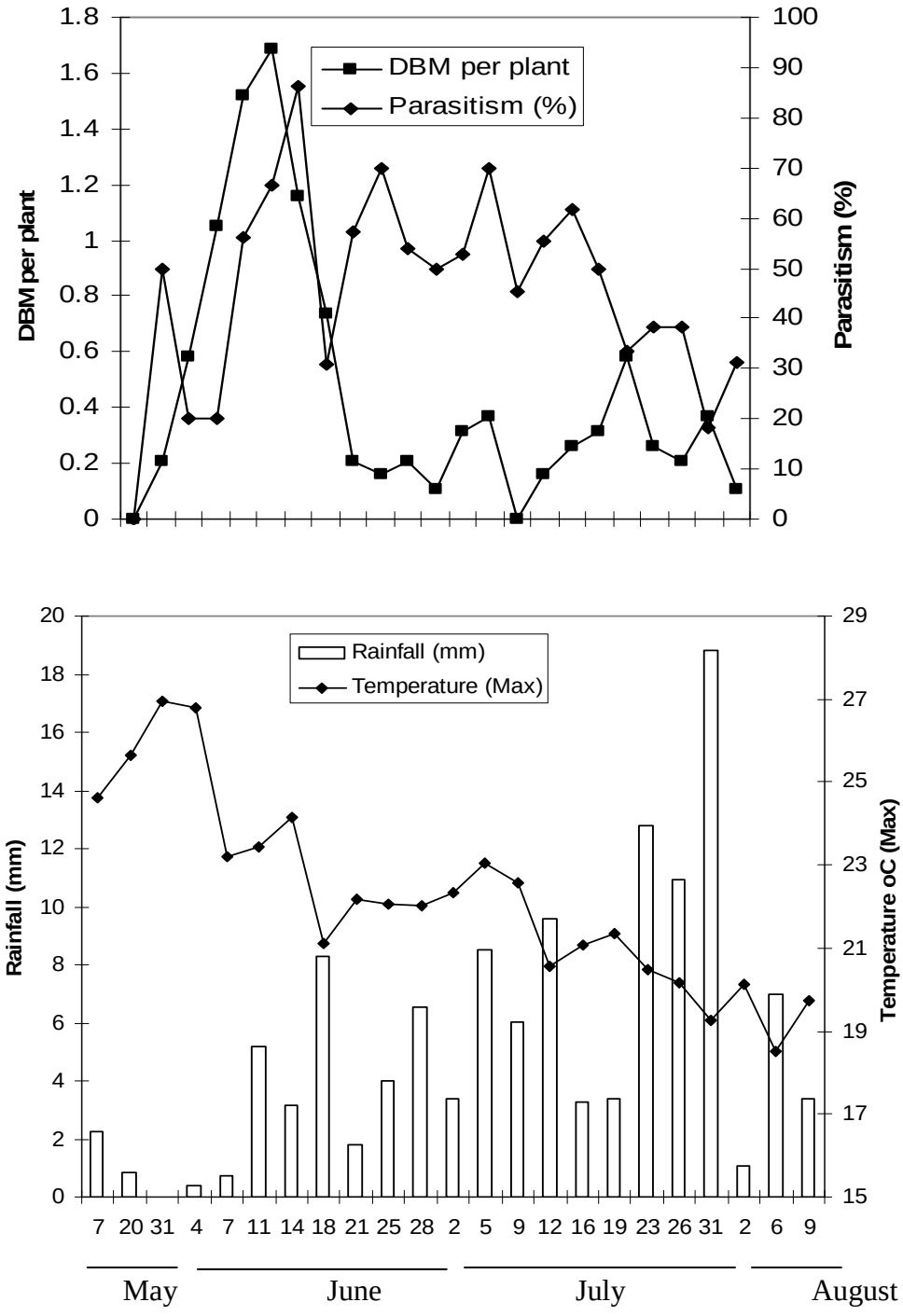


Fig. 1. Changes in DBM population and its relationship to weather variables and parasitism on cabbage at Holetta (May to August 2002).

### Fruitworms on tomato

Seasonal variations in the population density of fruitworms, PTM and ABW (African bollworm, *Helicoverpa armigera*) were studied at the Melkassa Research Center of EIAR between 1992 and 1994. The proportion of fruits damaged by PTM was higher than that of ABW in all of the planting dates. The number of PTM damaged fruits ranged from 66.7-99%, while that of ABW was 1-33.3%. Similarly, the weight of damage fruits ranged from 65.7-99.4% for PTM and from 0.6-34.3% for ABW (Ayalew and Desalegne, 2004). The damage by ABW increased on tomato planted between February and April which was ripened in the rainy season, indicating the importance of ABW in rain-fed tomato production.

In the periods until 1980s, ABW was the major pest of tomato fruits both in irrigated and rain-fed conditions. The reason for the shift to PTM in recent years is not clear (Abate and Ayalew, 1994; 1997). From studies conducted between 2000 and 2003 at the Melkassa Agricultural Research Center it was found that low level of α-tomatine contents in some tomato types especially the fresh market group and the provision of enemy free space by the tomato plants were responsible for the shift in importance from ABW to PTM (Mulatu et al, 2004; 2006a, b). In addition, the practice of growing tomato without staking and lack of crop diversification are also considered important cultural factors contributing to the importance of PTM in tomato production (Mulatu and Tadesse, 2004).

### Loss assessment

Yield losses caused by some of the major insect pests on commonly cultivated vegetables are shown in Table 4. Theses loss figures were generated from on-station trails conducted under heavy infestations. As such, it may not reflect the level of damage by a particular insect pest under farmers' field in different seasons of production.

# Management methods

## Onion thrips on onion

### Cultural

Dejene (2006) assessed the effect of mulching on thrips infestation at the Melkassa Research Center in 2004/05, and found that mulching onion plots with a white plastic sheet significantly ($P<0.05$) suppressed thrips population and consequently improved fruit yield compared to mulching with a black plastic sheet, tef straw and sawdust.

## Varietal

Thirty six onion germplasm introduced by the Vegetable Research Program at the Melkassa Research Center were evaluated for their susceptibility to thrips infestation in 2002 and 2003. The number of thrips/ 5 plants ranged from 13-45, 15-61, 1-7 at seedling, vegetative and maturity stages, respectively. Genotypes AC66 and Z-516 had less number of thrips than the standard check, Adama Red, at all growth stages.

## Botanical

Ethanol extracts of neem seeds and pepper tree (*Schinus molli*), and leaves of bersema (*Bersema abyssinica*) were evaluated during the 1995-1996 seasons at Melkassa for their efficacy against onion thrips. Results indicated that all of the treatments gave significantly lower ($P<0.05$) insect population than the untreated check, although the difference was not significant. It was suggested that the botanicals are more effective when applied at low thrips population levels than at the threshold established using synthetic insecticides (Ayalew, 2005). A similar study conducted at the Debre Berhan Research Center in 2003 and 2004 indicated that extracts of neem leaf, Garlic, Ginger, mixtures of Ginger, Garlic, and Chilli as well as Ginger, Garlic, Chilli and cow urine mixtures controlled thrips infestation and gave better yields than the synthetic pyrethroid, λ-cyhalothrin (karate) and the untreated check (DBARC, 2005).

## Insecticide control

Earlier studies conducted in the 1980s at Melkassa showed that cypermethrin was effective against onion thrips (Abate, 1983). Three to four sprays of cypermethrin at the rate of 50-75 g a.i. $ha^{-1}$ when the threshold of 5 thrips/ plant is exceeded was recommended (Abate and Ayalew, 1994). However, it was reported that the efficacy of cypermethrin to control thrips was declining. The efficacy of cyhalothrin and phenom were evaluated together with cypermethrin and the abovementioned botanicals in 1995 and 1996 at Melkassa, and it was found that cyhalothrin was better than all of the other treatments both in reducing thrips infestation and onion yield losses (Ayalew, 2005). However, a decline in the efficacy of cyhalothrin against thrips is being observed in many onion fields in case if it is because of resistant development in the pest to cyhalothrin. DBARC (2005) reported that the performance of cyhalothrin was lower than that of the insecticide selecron and botanical treatments in an experiment carried out in 2003 and 2004 at Shoarobit. Nimbecidine 0.03% was reported to be as effective as the insecticides currently in use in 2003 and 2004 trials at Melkassa MARC, 2004).

### Biological control (entomopathogens)

The study conducted with entomopathogenic fungi, *Metarhizium anisopliae* at 1 x $10^7$ conidia $ml^{-1}$, *Beauveria bassiana* at 0.2 ml conidial suspension/ 100 ml of water, and *Paecilomyces fumosoroseus* biobe T® granules at 0.1 g /100 ml of water in the greenhouse in 2004 revealed that the three entomopathogens significantly ($P<0.01$) reduced thrips population and percentage of leaf area damaged compared to the untreated check (Mendesil et al., 2006).

### Management of tomato fruitworms

Research results on the management of PTM on tomato and ABW on hot pepper have been reviewed by Ayalew and Dessalegne (2004). These include varietal, cultural, botanical and insecticidal control methods.

### Varietal control

Eighty seven tomato germplasm introduced by Horticulture Research Division at Melkassa were evaluated for their resistance to fruitworms between 1992 and 1995. Pusa Early Dwarf, Pusa Ruby, Seedathing and Serio were reported to be resistant, while the commercial variety Marglobe was susceptible. Serio (now called Melka salsa) was also high yielder with marketable yield advantage of nearly 132% over Marglobe (Abate and Ayalew 1997; Ayalew and Dessalegne 2004).

### Insecticide control

The pyrethroids, cypermethrin and deltamethrin, were reported to be effective in reducing damage by the two fruitworms (MARC, 1986; Negasi, 1988). Experiments conducted in the 1990s to determine the critical period of fruit-worm infestation and to compare the insecticides with *Bacillus thuringiensis* var. kurstaki indicated that cypermethrin was more effective with treated plots suffering less (19.0 ± 2.2%) from fruit damage and number of worms/ 100 fruits (2.6 ± 0.5) than *Bt* with a corresponding fruit damage of 28.6 ± 1.3% and 5.8 ± 0.3 worms per 100 fruits. Early fruiting was reported to be the most important developmental stage of tomato at which control measure should be applied against fruitworms to effectively reduce losses in quality and quantity of the product (Ayalew and Dessalegne, 2004).

## Diamondback moth on cabbage

### Pesticide control

The synthetic insecticide λ-cyhalothrin (karate) and *Bt* were evaluated against DBM on cabbage at Melkassa for two seasons, November through March 2001 and April through July 2002. Results indicated that both treatments reduced the

population of DBM significantly ($P<0.05$) and increased cabbage yield, the synthetic insecticide yielded relatively more than the bio-pesticide treatment (Ayalew, 2006). In the Central Rift Valley where pesticides are used continuously karate failed to reduce DBM infestation and yield losses (Ayalew et al., 2004; Ayalew and Ogol, 2006). This is probably because of the presence of pesticide resistant DBM population and the low rate of parasitism because of the toxic effect of the pesticide on parasitoids.

## Termites on pepper

Studies conducted on the management of ABW in early 1980s were reported by Abate (1986) and Ayalew and Dessalegne (2004). Studies conducted on termite control during the last two decades are highlighted here.

## Insecticide control

Diazinon 60% EC at 2 l/ha and Chlorpyriphos (pyrinex) 48% EC at 2.5 l/ha applied as soil treatments at the vegetative and flowering stages of hot pepper reduced termite damage and increased pod yield compared to the untreated check. Applications of Chlorpyriphos at the vegetative stage and Diazinon during transplanting were found to be effective (BARC, 2000).

## Cultural control

Studies on the effects of mulching with maize stover at 26 kg/17 $m^2$, haricot bean residues, grass and tef straw each at 15 kg/17$m^2$ compared with Diazinon 60% EC and an untreated check indicated that the maize stover, haricot bean residue and grass mulches were as effective as the synthetic insecticide, and gave higher yields and lower rates of termite damage (BARC, 2004).

## Botanical control

The effects of 12 different botanicals were compared with Diazinon and an untreated check in the 2001 and 2003 seasons at the Bako Research Center, and it was found that *Maesa lanceolata* and *A. indica* leaves were more effective than the other treatments (BARC, 2003).

## Demonstration and promotion of IPM

A collaborative project was carried out between the Ethiopian Institute of Agricultural Research (EIAR) and the International Center of Insect Physiology and Ecology (ICIPE) between 1999 and 2001 to develop IPM options for sustainable vegetable cultivation by small scale growers through: improving farmers perception of pest problems, knowledge of pest identification and damage caused through group learning; building awareness on the safe and proper use of pesticides; and identification of suitable options.

The criteria applied for choosing IPM options included adequacy of research results, availability of inputs, and potential for adoption by farmers, socioeconomic viability and experience gained elsewhere (Table 3).

Table 3. Results of diagnostic study on IPM options for major insect pests of major vegetable crops at Wonji, Ethiopia, 1998 (after Yesuf et al., 2006).

| **Crop** | **Pest/disease** | **Options** | **Criteria of evaluation** | | | | | **Average** |
|---|---|---|---|---|---|---|---|---|
| | | | **A** | **B** | **C** | **D** | **E** | |
| Tomato | Fruit worms | chemical | 1 | 2 | 2 | 3 | 2 | 2* |
| | | varietal | 2 | 2 | 2 | 1 | NA | 1.75* |
| | | biological | 3 | 3 | 3 | 4 | NA | 3.25 |
| | | botanical | 5 | 5 | 5 | 5 | 5 | 5 |
| Onion | Onion thrips | chemical | 1 | 2 | 2 | 3 | 2 | 2* |
| | | varietal | N/A | 4 | 5 | 4 | 5 | 3.6 |
| | | biological | 5 | 5 | 5 | 5 | 5 | 5 |
| | | botanical | 2 | 3 | 2 | 3 | 2 | 2.4* |
| Cabbage | DBM | chemical | 4 | 2 | 2 | 3 | 2 | 2.6* |
| | | varietal | 4 | 4 | 3 | 3 | 3 | 3.4 |
| | | biological | 4 | 2 | 2 | 3 | 2 | 2.6 |
| | | botanical | 4 | 2 | 3 | 2 | 1 | 2.4* |

Criteria A = adequacy of research result, B = input availability, C = potential for impact, D = socioeconomic viability, E = external experience.
Scores**:** 1 = Excellent, 2 = Very good, 3 = Good, 4 = Satisfactory, 5 = Not satisfactory, NA = Not applicable, * potential options recommended for on farm test.

Among the major target crops, tomato, cabbage and onion, five insect pests were included to evaluate different IPM options. The insect pests considered were PTM and ABW on tomato, DBM and cabbage aphid on cabbage and onion thrips on onion. The major lessons learned from the project include:

- Farmers' group could be motivated and actively participate if the project is developed based on their needs;
- Farmers' group members could identify major insect pests of vegetable crops they are growing;
- Farmers are aware of the range of the insecticide groups for insect pest control and their rational use in vegetable pest management;
- Farmers are aware oft the existence of natural controlling factors such as parasitoids and the care they need to take to use them as a component of IPM;
- Farmers are aware of the availability of non-chemical options of pest control and the benefit that could be obtained from options demonstrated on farm. These include:
    - Availability of resistant varieties for the management of fruitworms on tomato

  - Use of botanicals and biological products for DBM management on cabbage
- The approach employed was found to be time and resource demanding as it required frequent visit to farmers' group.
- Unavailability of registered pesticides in the local market was observed to be the major reason for use of banned or restricted pesticides by most vegetable farmers

# Conclusion and recommendations

A number of insect pests attack the different vegetable crops in Ethiopia. However, only a few are economically important. These include onion thrips on onion, DBM and cabbage aphid on cabbage, PTM and ABW on tomato and termites and ABW on hot pepper. Recently, spider mites (*Tetranychus* spp.) and white flies are becoming important in irrigated tomato production. The main control option available is pesticide use. This continuous use of the same insecticides over an extended period appeared to result in the development of resistance in some pests.

The following recommendations are available for the management of major vegetable pests on commonly grown vegetable crops;

Use of water extract of neem seed powder at the rate of 50 g/l of water and *Bt* at 0.5 kg/ha has proved effective against DBM on cabbage. In newly established brassica farms, application of λ-cyhalothrin 5 EC (karate) at 16 g a.i./ha can give effective control.

Fruitworms could be effectively controlled by the use of resistant varieties and judicious use of insecticides i.e. application of insecticides at critical growth stages. For example, Serio (Melkassalsa) is a tomato variety that is resistant to fruitworms and is a high yielder. Application of cypermethrin at 75-100 g a.i /ha once at early flowering and another one at early fruiting can give effective protection against both fruitworms. For intermediate type tomatoes, staking can minimize PTM damage.

The efficacy of cypermethrin (75 g ai/ha) and cyhalothrin (16 g ai/ha) against onion thrips has declined in recent years in some localities. In those situations, effective control of onion thrips could be achieved by using Ethiothioate and Selecron. Some onion accessions such as AC-66 and Z – 516 have been found to be less susceptible to thrips infestation. Seeds of neem and pepper tree, and leaf of bersema (*Bersema abyssinica*) provided significant reduction in the

population of onion thrips. Their use in thrips control, however, requires further assessment of rate and frequency of application.

Termites on hot pepper can be controlled by Diazinon 60% EC at 2 l /ha and Chlorpyriphos (pyrinex) 48% EC at 2.5 l/ha applied as soil treatments at the vegetative and flowering stages. Mulching with maize stover, haricot bean residues and grass also helps to minimize termite damage.

## Gaps and challenges

As has been mentioned earlier a decline in efficacy of the commonly used insecticides is apparent and the population of some major pests resistant to insecticides is on the increase. For example, the onion thrips has developed resistance to pyrethroid insecticides (cypermethrin and cyhalothrin) in recent years. Currently, selecron (organophosphate) is preferred by both state farms and small scale growers. However, selecron is a broad-spectrum insecticide that is not compatible with IPM program.

The problem associated with the use of insecticide in vegetable production is aggravated, among other things, by the lack of periodic study on the occurrence of insecticide resistance and resistance management strategies. The only reported study by Terefe and Jamornmarn (2005) is on ABW that showed insecticide types used and areas in Ethiopia where the pest has developed resistance.

Knowledge on the ecology and natural enemy complex of the major pest species is a key in promoting biological control program. Unfortunately, no such information is available except a few reports on general surveys. There is some fragmented information available from thesis work by graduate students. However, no efforts were exerted to strengthen and utilize such information in the country. The experience in Kenya shows that classical biological control of DBM using a hymenopteran parasitoid (*Diadegma semiclausum*) made production of brassica possible without the need for insecticides within two to three years of the release of the parasitoid.

Application of control methods using threshold level is a key factor in integrated pest management programs. Pesticide application based on threshold level is practiced no where in Ethiopia both on stations and on small scale and state farms, although the latter follows general observation of infestation level as a pest monitoring scheme in some cases. Although there is no threshold level for pests of economic importance on vegetable crops in Ethiopia, 5 thrips/ plant is regarded as a threshold level for pesticide application (Abate and Ayalew, 1994; Abate, 1995). These needs to be verified through appropriate study and similar studies should be

conducted for other major vegetable pests. Development of a sampling plan for decision making in pest management program is crucial in this regard (Ayalew et al., 2006c).

The importance of a certain pest varies from location to location because of differences in environmental variables as well as agronomic practices (Ayalew and Ogol, 2006). Hence, studies on the spatial ecology of the major insect pests are necessary to delimit areas with high infestation for consideration in both monitoring and biological control programmes (Ayalew et al., 2007).

On-farm demonstration of available pest management technologies will improve farmers' perception of pest problems, their knowledge on insect pest recognition and rational use of insecticides. The recent experience of the EIAR and ICIPE on IPM of vegetable crops in the Wonji area showed promising results (Yesuf et al., 2006).

Surveys and monitoring of vegetable insect pests must be conducted periodically to detect changes in pest status with the aim of developing options for the management of the key ones before a serious damage is inflicted in a wider geographic area. For example, spider mites (*Tetranychus* spp.) were not major pests of tomato in the 1990s. Currently they probably rank first as pests of tomato but there is no single recommendation for their management. Therefore, studies on miticides and other alternative options to develop IPM of spider mites on tomato are imperative. Although the occurrence of the tobacco whitefly (*Bemisia tabaci*) on tomato is well known (Abate, 1988a), their significance is increasing in recent years especially in the warmer seasons of February through May (Ayalew, unpublished). The tobacco whitefly is also a vector of the tomato yellow leaf curl virus (TYLCV). Hence, attention should be given to the development of options for their management.

The potential of botanicals in mitigating damage by several pests is evident from several reports. However, their implementation as part of pest management strategies is limited. The only notable attempt made to implement the use of botanicals is against the DBM and onion thrips in the Wonji area (Yesuf et al., 2006).

Resistance sources for tomato fruitworms and onion thrips should be identified and used in developing varieties.

Minimizing pest infestation through modifying the crop environment is an important component of IPM. This did not receive adequate research attention to date.

## Prospects

Based on the challenges and gaps outlined, the following research areas in vegetable entomology are suggested for future consideration.

- Surveys must be conducted periodically to detect the occurrences and changes in pest status with the aim of developing management options before serious damage is inflicted in a wider geographic area;
- Periodic screening of reportedly safe, selective and effective insecticides;
- Monitoring the occurrences of insecticide resistance and developing resistance management strategies and related problems;
- Development of sampling plans and determination of threshold levels for decision making in the IPM of vegetables crops is important
- Surveys and ecological studies on natural enemies of major pests of vegetable crops need to be carried out with the aim of establishing and promoting biological control and IPM
- Studies on other management options such as botanical control need to be strengthened;
- Continues screening of germplasm to identify resistance sources to the major insect pests of different vegetable crops – in collaboration with international organizations such as the Asian Vegetable Reseach and Development Center (AVRDC) is crucial;
- Cultural control measures available to date should be verified and incorporated into IPM strategy for the different vegetable crops
- Strengthening on-farm demonstration of available pest management options to farmers would facilitate adoption of the options by growers.

Appendix 1. Insect pests recorded on hot pepper in Ethiopia.

| **Scientific name** | Common name | Status | References |
|---|---|---|---|
| **Acarina** | | | |
| **Eriophyidae** | | | |
| *Aceria lycopersici* | Tomato erinose mite | unknown | 3 |
| **Tarsonemidae** | | | |
| *Polyphagotarsonemus latus* | Yellow tea mite | minor | 3 |
| **Coleoptera** | | | |
| **Meloidae** | | | |
| *Epicauta albovittata* | Striped blister beetle | minor | 3 |
| *Epicauta tomentosa* | Striped blister beetle | minor | 3 |
| **Malachiidae** | | | |
| *Hedybius sp. nr. aulicus* | Pepper beetle | minor | 3 |
| **Diptera** | | | |
| **Tephritidae** | | | |
| *Ceratitis capitata* | Mediterranean fruit fly | minor | 3 |
| *Ceratitis rosa* | Metal fruit fly | minor | 3 |
| **Heteteroptera** | | | |
| **Pyrrhocoridae** | | | |
| *Dysdercus* spp | Cotton strainers | minor | 3 |
| **Homoptera** | | | |
| **Aphididae** | | | |
| *Aphis gossypii* | Cotton aphid | minor | 3 |
| *Macrosiphum euphorbiae* | Pepper aphid | Minor | 3 |
| *Myzus persicae* | Peach aphid | minor | 3 |
| **Aleyrodidae** | | | |
| *Bemisia tabaci* | Tobacco whitefly | minor | 3 |
| **Isoptera** | | | |
| **Termitidae** | | | |
| *Macroterms* spp. | termites | Major | 3 |
| *Microtermes* spp | termites | Major | 3 |
| **Lepidoptera** | | | |
| **Noctuidae** | | | |
| *Diachrysia orichalcea* | Golden plusia | minor | 3 |
| *Spodotera littoralis* | Cotton leaf worm | minor | 3 |
| *Heliothis armigera* | African bollworm | minor | 3 |
| *Cryptophlebia leucotreta* | Cryptophlebia leucotreta | minor | 3 |
| **Gelechiidae** | | | |
| *Phthorimaea operculella* | Potato tuber moth | | |
| **Orthoptera** | | | |
| **Pyrgomorphidae** | | | |
| *Zonocerus variegatus* | Variegated grasshopper | minor | 3 |
| **Acrididae** | | | |
| *Cyrtacanthacris tatarica* | Brown-spotted grasshopper | minor | 3 |
| **Thysanoptera** | | | |
| **Thripidae** | | | |
| *Thrips tabaci* | Onion thrips | minor | 3 |

Appendix 2. Insect pests recorded on cabbage in Ethiopia.

| **Scientific name** | Common name | Status | Reference |
|---|---|---|---|
| **Coleoptera** | | | |
| **Chrysomelidae** | | | |
| *Aphthona* sp. | Aphthona beetle | Minor | 3 |
| *Phyllotreta atra* | Cabbage flea beetle | Major | 11 |
| *Phyllotreta mashonana* | Cabbage flea beetle | Major | 11 |
| *Phyllotreta weisei* | Cabbage flea beetle | Major | 11 |
| **Curculionidae** | | | |
| *Ceuthorhynchus* sp | Amaranthus weevil | Minor | 3 |
| *Lixus latro* | Cabbage weevil | Minor | 3 |
| **Tenebrionidae** | | | |
| *Gonocephalum patruele* | Dusty radish beetle | Minor | 3 |
| **Lagriidae** | | | |
| *Lagria villosa* | Metallic leaf beetle | Minor | 3 |
| **Collembolla** | | | |
| **Entomobryidae** | | | |
| *Entomobrya purpurascens* | Cabbage springtail | Minor | 3 |
| **Diptera** | | | |
| **Agromyzidae** | | | |
| *Liriomyza brassicae* | Cabbage leaf miner | Medium | 3 |
| *Phytomyza horticola* | Chrysanthemum leaf miner | Minor | 3 |
| **Heteroptera** | | | |
| **Pentatomidae** | | | |
| *Bagrada hilaris* | Bagrada bug | Medium | 3 |
| *Eurydema ornata* | Cabbage bug | Minor | 3 |
| **Homoptera** | | | |
| **Aphididae** | | | |
| *Brevicoryne brassicae* | Cabbage aphid | Major | 11 |
| *Lipaphis erysimi* | Mustard aphid | Minor | 3 |
| *Myzus persicae* | Peach aphid | Minor | 3 |
| **Hymenoptera** | | | |
| **Tenthredinidae** | | | |
| *Athalia schweinfurthi schweinfurthi* | Cabbage sawfly | Minor | 3 |
| **Orthoptera** | | | |
| **Gryllidae** | | | |
| *Gryllus bimaculatus* | Two spotted cricket | Minor | 3 |
| **Lepidoptera** | | | |
| **Noctuidae** | | | |
| *Diachrysia orichalcea* | Golden plusia | Minor | 3 |
| *Spodoptera littoralis* | Cotton leaf worm | Minor | 3 |
| **Pyralidae** | | | |
| *Hellula undalis* | Cabbage webworm | Medium | 3 |
| **Pieridae** | | | |
| *Pieris brassicoides* | Cabbage white | Medium | |
| **Ypononeutidae** | | | |
| *Plutella xylostella* | Diamond back moth | Major | 11 |

Appendix 2. Cont'd.

| **Scientific name** | Common name | Status | Reference |
|---|---|---|---|
| **Nymphalidae** | | | |
| *Vanessa cardui* | Painted lady | Minor | 3 |
| **Thysanoptera** | | | |
| **Thripidae** | | | |
| *Thrips tabaci* | Onion thrips | medium | 3 |

Appendix 3. Insect pests recorded on onion in Ethiopia.

| **Scientific name** | Common name | Status | Reference |
|---|---|---|---|
| **Acarina** | | | |
| **Tetranychidae** | | | |
| *Tetranychus* sp. | Onion spider mite | Minor | 3 |
| **Lepidoptera** | | | |
| **Arctiidae** | | | |
| *Utetheisa lotrix* | Speckled tiger moth | Minor | 3 |
| **Noctuidae** | | | |
| *Diachrysia orichalcea* | Golden plusia | Minor | 3 |
| *Spodoptera exigua* | Lesser army worm | Minor | 3 |
| **Psocoptera** | | | |
| **Lipocelidea** | | | |
| *Liposcelis* sp. | Onion springtail | Minor | 3 |
| **Thysanoptera** | | | |
| **Thripidae** | | | |
| *Frankliniella occidentalis* | Western flower thrips | Unknown | 24 |
| *Thrips tabaci* | Onion thrips | major | 3 |

Appendix 4. Insect pests recorded on tomato in Ethiopia.

| **Scientific name** | Common name | Status | Ref. |
|---|---|---|---|
| **Acarina** | | | |
| **Eriophyidae** | | | |
| *Aceria lycopersici* | Tomato erinose mite | Unknown | 3 |
| *Aculops lycopersici* | Tomato russet mite | Minor | 3 |
| **Acarina** | | | |
| **Tetranychidae** | | | |
| *Tetranychus* spp. | Red spider mite | Major | G |
| **Coleoptera** | | | |
| **Lagriidae** | | | |
| *Lagria villosa* | Metallic leaf beetle | Minor | 3 |
| **Diptera** | | | |
| **Tephritidae** | | | |
| *Dacus bivittatus cucumarius* | Cucurbit fly | Minor | 3 |
| *Dacus ciliatus* | Lesser melon fly | Minor | 3 |
| **Heteroptera** | | | |
| **pentatomidae** | | | |

Appendix 4. Cont'd.

| **Scientific name** | Common name | Status | Ref. |
|---|---|---|---|
| *Agonoscelis pubescens* | Cluster bug | Minor | 3 |
| **Heteroptera** | | | |
| **Miridae** | | | |
| *Nesidiocoris tenuis* | Tomato bug | Minor | 3 |
| **Lygaeidae** | | | |
| *Spilostethus pandurus* | Red bug | Minor | 3 |
| **Homoptera** | | | |
| **Aphididae** | | | |
| *Aulacorthum solani* | Potato aphid | Minor | 3 |
| *Saltusaphis scirpus* | Alfalfa aphid | Minor | 3 |
| *Therioaphis trifolii form maculata* | Spotted alfalfa aphid | Minor | 3 |
| **Aleyrodidae** | | | |
| *Bemisia tabaci* | Tobacco white fly | Major | 3 |
| *Trialeurodes vaporariorum* | Greenhouse white fly | Minor | 3 |
| **Homoptera** | | | |
| **Cicadellidae** | | | |
| *Empoasca lybica* | Cotton jassid | Minor | 3 |
| **Lepidoptera** | | | |
| **Sphingidae** | | | |
| *Acherontia atropos* | Death's-head hawk moth | Minor | 3 |
| **Gelechiidae** | | | |
| *Phthorimaea operculella* | Potato tuber moth | Major | 3 |
| **Noctuidae** | | | |
| *Heliothis armigera* | African bollworm | Major | 12 |
| **pyralidae** | | | |
| *Leucinodes orbonalis* | Egg plant fruit borer | Minor | 3 |
| **Arctiidae** | | | |
| *Syntomis alicia* | Tomato tiger moth | Minor | 3 |
| **Orthoptera** | | | |
| **Tettigoniidae** | | | |
| *Eugasteroides loricatus* | Spiny bush cricket | Minor | 3 |
| **Pyrgomorphidae** | | | |
| *Phymateus pulcherimus* | Bush locust | Minor | 3 |
| *Phymateus viridipes* | Bush locust | Minor | 3 |
| **Thysanoptera** | | | |
| **Thripidae** | | | |
| *Thrips tabaci* | Onion thrips | Minor | 3 |

G = Gashawbeza Ayalew pers. observation.

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# Review of Entomological Research on Fruit Crops in Ethiopia

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## Introduction

Several species of fruit crops are grown in Ethiopia including citrus, grape, pineapple, banana, papaya, avocado, mango and temperate fruits like peach and apple. The various fruits are produced in different capacities. There are large commercial fruit farms owned mainly by the state and increasingly large sized private farms are being developed in many areas. In addition, small holders produce varied types of fruits in their backyards mainly for home consumption and supply the nearby local markets. The largest fruit farms of Ethiopia are found in the Rift Valley which includes the Showa Robit, Upper Awash Agro-Industry Enterprise (UAAIE), and Metahara. Although the expansion of fruit crops is not at the same par with the flowers and vegetables, there are initiatives in the distribution of good quality apple, citrus, mango, avocado, etc. varieties all over the country. Most of the fruits produced in Ethiopia are consumed within the country while there is little export to neighbouring countries.

Fruit crops in Ethiopia are attacked by numerous insect pests which has been one of the challenges in the development of the sector. Previous works on fruit crop entomology focused on documentation of arthropods attacking these crops and prioritizing their importance (Abate, 1995). However, the statuses of the listed pests are not known. Research on population dynamics and management options had been carried out against armoured scales on citrus which was considered important pest of citrus until 1985 (Abate, 1986). In the recent years, pests which previously were not considered as major have become more important in various fruit crops. One of the reasons for such shift of pest status might be due to increased use of pesticides that disturb the natural control. This paper reviews research activities carried out on fruit crops in Ethiopia.

# Research findings

## Insect pests recorded

Many arthropod species have been recorded as pests of various fruit crops in Ethiopia (Appendix 1). Tsedeke (1987) reported 60 species of insects to be recorded on fruit crops of which only armoured scales were the key pests. Citrus has the largest share of these pests indicating that the other fruit crops are less studied. Homopterous insects are by far the most important both in terms of the number of species recorded and the economic damage they cause on fruit crops in the country. The most important insect pests of fruit crops include the red scale (*Aonidiella aurantii*), purple scale (*Chrysomphalus aonidum*), black scale (*Parlatoria ziziphus*) and orange scale (*Chrysomphalus dictyospermi*), fruit flies (*Ceratitis capitata*, *C. fasciventris*, *Bactrocera invadens*), false codling moth (*Crytpophlebia leucotreata*), citrus thrips (*Scirtothrips aurantii* Faure), citrus leaf miner (*Phyllocnistis citrella* Stainton), citrus woolly whitefly (*Aleurothrixus floccocus* (Maskell)), and apple woolly aphid (*Eriosoma langigerum* (Hausman)). The statuses of most of the pests recorded on fruit crops in the country are not known. Some of them are records of occasional encounters. Many insects were recorded from Eritrea and there is little follow up if they have spread to the Ethiopian inland and gained economic importantance.

The red scale (*A. aurantii*) is one of the few insects pests of citrus better studied. Red scale is widely distributed in Ethiopia, especially in the citrus belt along the upper and middle Awash and many citrus-growing areas. The peak breeding periods of red scale were observed following the rainy season in September/ October and March/ April (Tsedeke, 1984). Purple scale occurs together with red scale on citrus and is common in Dire Dawa, Koka areas, near Wonji, and in the surroundings of Awassa. Black scale is restricted to the citrus plantation at Gibe and in small gardens (often neglected trees) of some parts of Kefa and Wello. It is not recorded on plants other than citrus and hence its spread can be minimized by restricting movements of fruit or planting materials from infested areas (Tsedeke, 1992).

Citrus woolly whitefly (*A. floccocus*) is a newly introduced pest into Ethiopia and first recorded in 2000 and identified by the International Centre of Insect Physiology and Ecology (ICIPE) in 2001 (Emana et. al., 2001). The pest is native to tropical and subtropical America. It was recorded in Kenya in 1990 and has been recorded in other African countries including North Africa, Uganda, Tanzania, Zambia, Malawi, Mozambique, and Zimbabwe. The pest was mentioned by Tsedeke (1992) as pest of potential importance to enter and invade Ethiopia. Today, it is well established and distributed in the central Rift

Valley areas like Nazareth, Debre Zeit, Wonji, Melkassa, Meki, Merti (UAAIE) and Ziway and eastern Wollega (Nekemt area). Individuals who are growing citrus on their homestead in the above-mentioned areas are reporting that citrus plants are dying from heavy infestation of the pest. Currently, the pest has become well established (Emana Getu, pers. com.).

The false codling moth (*Cryptophlebia leucotreta*) used to be a minor pest of citrus until recently. A serious outbreak was observed on avocado in the Upper Awash in December 1985 (Tsedeke, 1992). However, it has recently emerged as the most important insect on citrus following the fruit fly in upper awash (UAAIE, 2006). Larvae feed just under the fruit peel, making chemical control difficult. Up to now there is no a method recommended for this pest and it remains to be a menace of fruit production. Sorghum is reported to be one of the trap crops that can be used in the integrated management of false codling moth, however, there is no detailed study how to integrate this method in the field (Tsedeke, 1992).

Heavy infestations of young citrus leaves, grapefruit and lemon in particular, caused by the citrus leaf miner (*P. citrella*) occur throughout the citrus growing regions of Ethiopia. Local outbreaks of the pest that occurs in some seasons appear to be effectively controlled by the eulophids *Cirrosphilus* spp. (Tsedeke, 1991). Recently, the insect has become more important at UAAIE (MARC, 2006 and UAAIE, 2006). The citrus thrips *S. aurantii* has become an important pest recently and well established in the fruit farms in the Rift Valley area and causes heavy scarifications on citrus fruits (UAAIE, 2006).

Many species of fruit flies are important pests of fruit crops. Of these, the Mediterranean fruit fly (*C. capitata*) had been a major pest of citrus causing heavy fruit drop. Detailed studies on the species composition fruit flies attacking various fruits in the country are lacking. A survey was conducted in 2007 by the Hawassa University and Melkassa Research Centre (MARC) to record the species of fruit flies that attack different fruit crops in some selected fruit production areas which included the Central Rift Valley, North Shoa, South Wollo, eastern Ethiopia, southern Ethiopia and Gambella regions. Samples were mainly collected from citrus, guava, and mango. The Mediterranean fruit fly was present in all of the areas. In the eastern Ethiopia and the central Rift Valley regions, *Certatine* species, *C. capitata* and *C. fasciventris* are the dominant species. *C. fasciventris* was earlier identified on mangoes at UAAIE (Birtukan, 2006). *C. fasciventris* has been reared from fruits of citrus, guava and mango collected from farms in Metahara, UAAIE, Welkitie, Jimma/ Sokoru. *B. invadens* has become very important pest of mango and guava and recorded mainly from southern and western Ethiopia including Arbaminch, Asossa, Arjo, Bako, Gambella, Gibe, Ghimbi, and

Welkitie on guava and mango (Ferdu Azerefegne and Difabachew Belay, unpublished data). The newly described species of *B. invadens* appears to have invaded Africa from Sri Lanka. In Africa, it has been detected in Kenya and Tanzania in 2003 and it had spread to more than 11 countries in Central Africa where it is reported as pest of economic importance (Drew et al., 2006). This fruit fly is highly invasive and polyphagous with high reproductive potential. Known hosts of the pest are citrus, mango, cashew, papaya, guava, pepper, and several wild host plants.

## Extent of damage on citrus by pests at UAAIE

Studies on the extent of fruit damage by insect pests on various varieties of citrus at UAAIE showed that thrips, fruit flies, scales and false codling moths are important (Tables 1 and 2).

Table 1. Extent of fruit infestation of sweet orange varieties by different insect pests in 2004/ 05 at the Upper Awash Agro-Industry Enterprise (UAAIE, 2006).

| Orange varieties | Months | Infestation by different insect pests (%) | | | | Total infested (%) |
|---|---|---|---|---|---|---|
| | | Thrips | Scale insects | Fruit fly | False codling moth | |
| *C. valencia* | March | 39.71 | 6.72 | 7.33 | 1.22 | 64.15 |
| | April | 35.77 | 27.31 | 11.92 | 3.85 | 78.77 |
| | May | 27.66 | 13.83 | 14.89 | 0.35 | 56.74 |
| | June | 15.52 | 8.06 | 1.81 | 0.4 | 25.81 |
| *O. valencia* | March | 31.13 | 9.86 | 7.89 | 1.24 | 50.11 |
| | April | 33.5 | 8.44 | 22.08 | 0.99 | 65.01 |
| | May | 33.75 | 8.95 | 28.93 | 1.15 | 72.73 |
| | June | 22.29 | 0.49 | 15.71 | 0.61 | 39.1 |
| Hamlin | March | 9.88 | 4.07 | 48.26 | 19.19 | 81.4 |
| | April | 19.2 | 21.13 | 30.41 | 13.3 | 84.04 |
| | May | 27.83 | 16.93 | 43.42 | 9.85 | 98.01 |
| | June | 19.06 | 11.56 | 46.16 | 9.13 | 84.91 |
| *W. navel* | March | 6.56 | 3.28 | 4.3 | 32.17 | 46.31 |
| | April | 15.15 | 13.93 | 0.93 | 12.86 | 42.87 |
| | May | 24.11 | 13.87 | 1.68 | 14.91 | 54.57 |
| | June | 33.29 | 9.95 | 1.66 | 21.8 | 66.71 |
| Pineapple | March | 23.7 | 9.83 | 2.07 | 21.43 | 57.03 |
| | April | 18.98 | 7.86 | 21.25 | 0.48 | 48.57 |
| | May | 9.45 | 5.34 | 23.41 | 0.97 | 39.18 |
| | June | 19.96 | 11.81 | 32.55 | 4.34 | 68.66 |
| Jafa | March | 4.4 | 20.88 | 38.46 | 24.18 | 87.91 |
| | April | 0 | 0 | 0 | 0 | 0 |
| | May | 0 | 0 | 0 | 0 | 0 |
| | June | 0 | 0 | 0 | 0 | 0 |

Table 2. Extent of fruit infestation of Mandarin varieties by different insect pests in 2004/05 at Upper Awash Agro Industry Enterprise (UAAIE, 2006).

| Mandarin varieties | Months | Infestation by different insect pests (%) | | | | Total infested (%) |
|---|---|---|---|---|---|---|
| | | Thrips | Scale insects | Fruit fly | False codling moth | |
| A. tangerine | March | 22.22 | 22.22 | 0 | 0 | 44.44 |
| | April | 20.66 | 17.36 | 0 | 1.65 | 39.67 |
| | May | 32.37 | 11.24 | 1.45 | 3.86 | 47.92 |
| | June | 35.38 | 13.72 | 2.53 | 5.78 | 57.4 |
| Nova | March | 15.38 | 7.69 | 53.85 | 0 | 76.92 |
| | April | 0 | 0 | 0 | 0 | 0 |
| | May | 27.66 | 21.28 | 4.26 | 0 | 53.19 |
| | June | 25 | 21.09 | 23.44 | 3.13 | 72.66 |
| Ponkan | March | 88.89 | 22.22 | 0 | 0 | 44.44 |
| | April | 0 | 0 | 0 | 0 | 0 |
| | May | 0 | 0 | 0 | 0 | 0 |
| | June | 13.91 | 7.65 | 12.17 | 17.39 | 51.13 |
| Orlando | March | 0 | 0 | 22.39 | 50.75 | 73.13 |
| | April | 23.6 | 1.66 | 11.14 | 24.84 | 60.25 |
| | May | 19.62 | 5.23 | 11.43 | 19.62 | 55.91 |
| | June | 25.46 | 5.7 | 13.54 | 30.4 | 75.11 |
| Minola | March | 23.53 | 0 | 8.82 | 29.41 | 61.76 |
| | April | 38.25 | 13.97 | 9.16 | 24.7 | 86.08 |
| | May | 30.69 | 6.2 | 3.21 | 20.56 | 60.66 |
| | June | 32.78 | 5.98 | 2.32 | 15.58 | 56.67 |
| Temple | March | 21.89 | 20.92 | 4.98 | 2.24 | 50.03 |
| | April | 24 | 16.73 | 4 | 1.09 | 45.82 |
| | May | 30.87 | 12.35 | 5 | 3.17 | 51.39 |
| | June | 44 | 18 | 11 | 6.2 | 78.2 |

Thrips scare the citrus fruits making them unsightly and rejected while sorting and grading. Such lower grade fruits might be used to process products like marmalade. The same happens with fruits highly infested with scale insects. In case of fruit fly and false codling moth damage, the loss is direct and final. Although the data were from one production cycle, some indicative and important results were obtained from a study on the pests of sweet oranges at Upper Awash. Among the sweet orange varieties, Hamlin, pineapple, and Valencia sustained higher levels of fruit fly infestations while Washington Navel was severely infested with the false codling moth. The mandarin varieties Nova, Orlando and Minola had higher levels of fruit fly attack while Orlando and Minola also were highly infested with false codling moth.

## Fruit fly species composition and extent of damage on mango at UAAIE

Two ceratatine fruit flies, *C. capitata* and *C. fasciventris*, were, identified attacking mangoes at UAAIE (Birtukan, 2006). This is the first record of *C. fasciventris* in the country. Rearing of the flies from infested fruits of mangoes showed that *C. capitata* is the dominant species in the area. Four-hundred twenty-five adult fruit flies were reared from the infested mango fruits of which 353 (83%) were *C. capitata*. On the other hand, females dominate the sex ratio of both species. Female flies represent 87% and 90% of the total flies reared for *C. capitata* and *C. fasciventris*, respectively.

Three hundred twenty adult flies were collected using Success Bait- GF 120) as attractant in a modified water bottle trap among which 292 (91.25%) were *C. fasiciventris* and 28 (8.75%) *C. capitata* (Birtukan, 2006). It seems that the bait strongly attracts *C. fasciventris* compared to *C. capitata*. The bait trapped both females and males; however, the proportion of trapped females was higher than the males in both species. The number of trapped fruit flies increased through time and the increase in the number of fruit flies coincided with the presence of abundant mature fruits in the field. Similar trends of fruit fly populations were observed on flies reared from fruits at three different times of the mango harvesting periods. Higher population density of the two fruit fly species were recorded for the later sampling date towards the last week of July (Fig. 1).

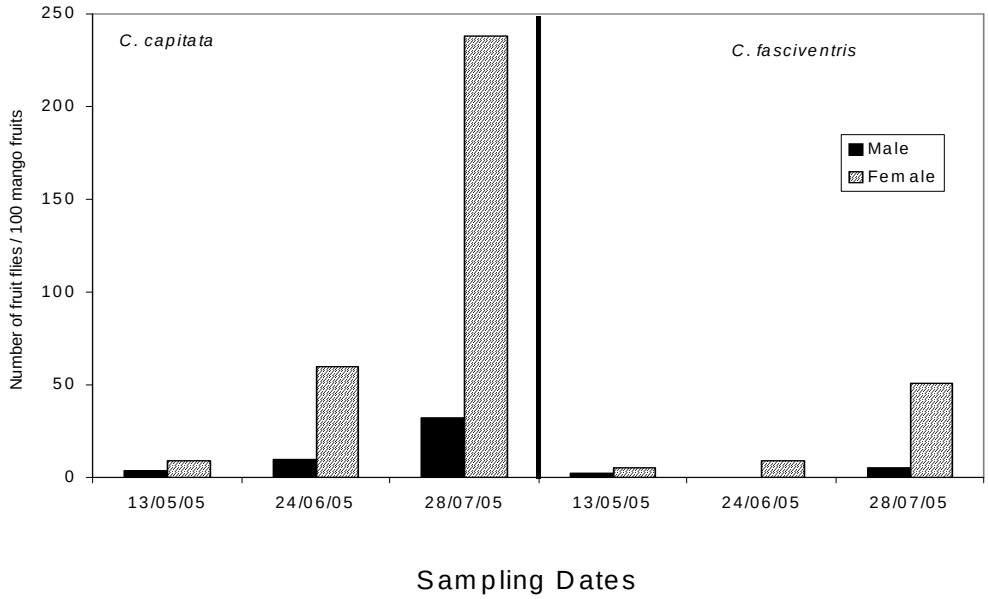


Fig. 1. Population of fruit flies reared from mango fruits at UAAEI (Birtukan, 2006).

The level of fruit fly infestation varied among different varieties of mango. The highest infestation was recorded on the variety Dodo with about 20% infested fruits (Appendix 2). The varieties Tommy Atkins, Keitt and the local variety "Abadir" had intermediate levels of infestation, while the lowest level of fruit infestations was observed on variety Kent. On the other hand, the highest amount of monetary loss was incurred by Dodo (11,481.08 Birr/ha) followed by Tommy Atkins (8,762.89 Birr/ha). The lowest monetary loss was recorded for variety Kent (2,900.37 birr/ha).

Fruits harvested at ripe stages had higher levels of infestations compared to those harvested at ripe but green stage (Table 3). There were significant differences in infestations between ripe and green ripe fruits irrespective of the varieties (P = 0.0001). The highest level of infestation at green ripe stage was observed on the variety "Abadir" (7.5%) followed by Dodo (5%) however, no infestation of the green mango fruits observed on variety Keitt.

Table 3. Infestation of mango fruits collected at ripe and green ripe stages (Birtukan, 2006).

| Mango varieties | No. of fruits sampled* | Infestation (%) | |
|---|---|---|---|
| | | Ripe fruits | Green ripe fruits |
| Tommy Atkins | 140 | 7.86 | 1.43 |
| Kent | 130 | 6.15 | 1.54 |
| Keitt | 90 | 8.89 | 0.00 |
| Dodo | 140 | 12.86 | 5.00 |
| "Abadir" | 200 | 17.00 | 7.50 |
| Total | 700 | 11.29 | 4.14 |

## Management of fruit flies using bait spray

The efficacy of Success Bait (GF-120 Naturalyte Fruit Fly Bait) was evaluated at UAAIE for the control of fruit flies on 55 ha of guava farm. Before applying the bait, assessments were conducted on the population density of the adult fruit flies and the extent of damages on guava fruits (Ferdu, 2006). Fruit weight loss was greater than 80% (Fig. 2). Success Bait application on the fruit trees reduced the population density of the adult fruit flies. The first spray reduced the catches from 18 to less than eight flies per trap. At the end of the fourth application only two flies were caught per trap on the average.

There was high reduction on the levels of guava fruit infestations. With the first application, the percentage number of infested guava fruits was reduced from 80% to 60% (Fig. 3) on the average. The reduction in the levels of infestation continued as the number of bait sprays increased. Fruits collected after the fourth bait applications had about 20% infestation. The weight loss of guava

fruits also was reduced because of the bait application (Fig. 4). The higher percentage of infested fruits at the time of the first bait application is because the fruits were already infested and had larvae inside. The reduction in infestation as a result of the bait spray was clearly observed on the subsequent three samplings. The four times applications of the bait reduced the weight loss to about 25%.

Assessments made after four times bait spraying showed that the population density of the fruit flies declined and the weight loss of guava fruits were reduced. The experiment clearly showed that Success Bait can control *Ceratitis* spp. and can be recommended for the control of fruit flies on guava and other fruits like citrus and mangoes that suffer from similar species of fruit flies. The bait is recommended as a component of integrated pest management to be combined with field sanitation and timely harvesting. Currently, UAAIE is using success bait on citrus extensively.

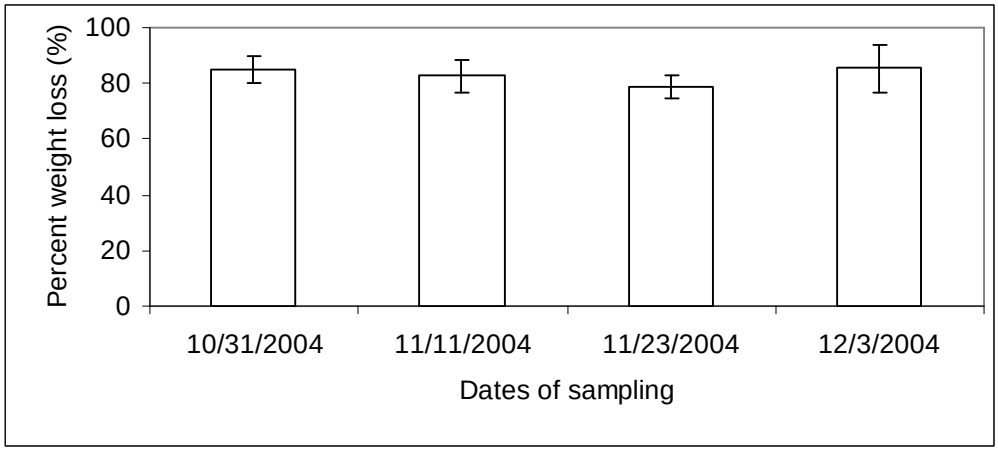


Fig. 2. Weight loss of guava fruits at UAAIE from fields before spraying with Success bait (GF 120), Error bars denote standard error of the mean (after Ferdu, (2006).

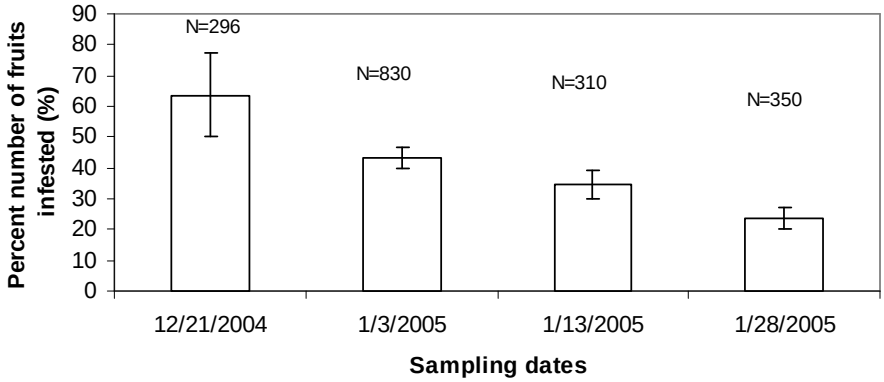


Fig. 3. Extent of guava fruits infested at UAAIE after spraying with Success bait (GF120) (after Ferdu, 2006).

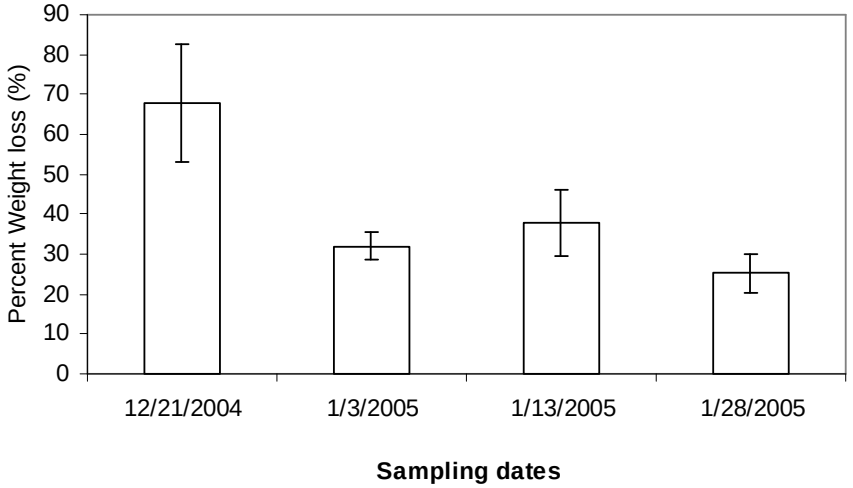


Fig. 4. Weight loss of guava fruits at UAAIE after spraying with success bait (GF 120) (after: Ferdu, 2006).

## Management of false codling moth

Observations made in 2004 at Nura-Era farm indicated that false codling moth is equally important to that of fruit flies (UAAIE, 2006). Currently, evaluation of insecticides and use of attractants are being conducted at UAAIE. Future studies shall focus on population dynamics study, biological control and mating disrupting pheromones. Routine sanitation of collecting and burying infested fruits is used to reduce the population and damage by false codling moth and fruit flies. The current practice of sanitation includes frequent collection of infested fruits to prepare compost and kill the fruit fly and false codling moth larvae.

# Management of red scale

## Chemical control

The red scale became a major pest of citrus orchards in the state farms during the late 1970s. It was common to observe monthly or even fortnightly blanket applications of organophosphate insecticides such as methidathion against this and other insects. An IPM program based on the understanding of the population dynamics of the pest and its natural enemies, and identification of selective insecticides was soon launched. The population dynamics studies were conducted between 1981 and l983. Breeding peaks were observed following the rains, one in October-November and the other in March-April. A large number of parasitoids and predators were also recorded; native species of Aphytis were the most important parasitoids; the ladybirds in the genera Chilocorus, Hyperaspis, etc. were important predators and their abundance increased with the increase in pest numbers.

Mineral oil (white oil) at the rate of 1.5-2.0% a.i. was found to give effective control of red scales. It has thus been recommended that a maximum of three sprays (1-2 in October-November, 1 in March-April) of white oil be applied per year (Tsedeke, 1983). These recommendations have been followed and at present the pest is no more a threat at UAAIE. Significant savings must have been realized from reductions in the frequency of pesticide applications; there must have also been obvious savings in terms of environmental safety.

## Biological control of scale insects and others

About a dozen species of indigenous parasitoids and predators have been recoded on the red scale and purple scale in Ethiopia (Tsedeke, 1991). An exotic parasitoid, *Aphytis holoxanhus*, imported from California and released at Koka during 1989 and 1980 was not established. Six species of parasitoids were recorded on soft brown scale in Ethiopia; those in the genus Coccophagus are most important (Tsedeke, 1991). The cottony cushion scale is a polyphagous insect attacking citrus and a number of crops across the country. A dozen of natural enemies including parasitoids (*Metaphycus* spp.) and predators (*Rodolia* spp.) were recorded on cottony cushion scale. These natural enemies might have contributed for checking of the populations of this insect.

It appears that the encyrtid egg parasitoid *Psyllecthrus oophagus*, keeps populations of the hoppers (Tettigometridae) below economic level (Tsedeke, 1991).The citrus psyllid is widespread in Ethiopia and about 11 species of parasitoids and predators have been recorded; the encyrtids, *Psyllaephagus* sp. and *Psyllaephagus pulvinatus* are important primary parasitoids.

The citrus leaf miner occurs throughout the citrus growing regions of Ethiopia. Local outbreaks of citrus leaf miner which occur in some seasons appear to be effectively controlled by the prarasitoid, eulophids *Cirrosphilus* spp. (Tsedeke, 1991). However, the economic importance of this pest is rising these days probably due to the disturbance of the balance with enemies.

Predaceous mites, such as *Typhlodromus magdalanae*, *Agistematus* sp., *Pronematus* sp., and *Pyemotes* sp. have been recorded from citrus orchards and vineyards in the Upper and the Middle Awash, but their status as natural biocontrol agents has not been determined. Moreover, *Phytoseilius persimillis* (Acari: Phytoseiidae) was imported from England in 1977 but failed to establish (Table 6).

Table 4. Efforts made in classical biological control in Ethiopia (Tsedeke, 1986).

| Natural enemies | Source country | Target pest | Date of release | Site of release | Status |
|---|---|---|---|---|---|
| *Rodalia cardinalis* (Col.:Coccinelidae) | Egypt | *Icerya purchasi* | 1946<br>1948<br><br>1954<br><br>1961<br>1971<br>1971 | Fagena<br>Fagena<br>Asmara<br>Imbatkla<br>Ginda<br>Alemaya<br>Asmara<br>Nazareth | E<br>E<br>E<br>E<br>E<br>NE<br>E<br>NE |
| *Phytoseilius persimillis* (Acri.: Phytoseiidae) | England | *Tetranychus* sp. | 1977 | Upper Awash | NE |
| *Cryptolaemus montrouzieri* (Col.:Cocc.) | California | *Planococcus* sp. citri | 1978<br><br>1979 | Melkawerer<br>Awash<br>Melka<br>Wonji | NE<br>NE<br>NE |
| *Aphytis cocheni* and *A. melinus (Hym*: Aphelinidae) | California | *Anoideiella aurantii* | 1979<br>1980 | Koka<br>Koka | NE<br>NE |
| *A. helaxanthus* (Hym.: Aphilinidae) | California | Chrysomphalus Aonidum(purple scale) | 1979<br>1980 | Koka<br>Koka<br>Erer Gota | NE<br>NE<br>NE |

NE: Not established after release, E: Established after release.

## Management of citrus leaf miner

Nine insecticides were screened for the control of citrus leaf miner for two seasons in 2004 and 2005 at UAAIE (Tables 1 and 2). Foliar application of Dynamec (vertimec) 1.8% EC (936 ml/ha), Virate 23% EC (624 ml/ha), bythroid EC 05 (500 ml/ha) or Karate 5% EC (624 ml/ha) gave better control and have been recommended (MARC, 2006).

Table 5. Mean (± SE) percent leaf infestation, number of mines and leaf miners per leaf on orange treated with different insecticides at Merti (Abadisca farm) in 2004 (MARC, 2006).

| Treatments | Leaf infestation (%) | No. of mines/leaf | No. of leaf miner larvae/ leaf |
|---|---|---|---|
| Dimethoate | 27.5 ± 4.1a | 2.2 ± 0.4 a | 0.40 ± 0.1 ab |
| Karate | 9.0 ±1.9 b | 1.1 ± 0.3 bc | 0.20 ± 0.0 bc |
| Baythroid | 7.6 ± 1.5 b | 0.6 ± 0.1 bc | 0.11 ± 0.0 bc |
| Pollo | 20.6 ± 3.1a | 1.6 ± 0.3ab | 0.20 ± 0.1abc |
| Vertimec (F) | 6.7 ± 1.6b | 0.6 ± 0.2c | 0.02 ± 0.02c |
| Vertimec (S) | 25.6 ± 3.4 a | 2.3 ± 0.4a | 0.50 ± 0.1a |
| Vertimec (F+S) | 7.6 ± 1.9b | 0.7 ± 0.1 bc | 0.08 ± 0.05 bc |
| Actara | 8.8 ± 1.5b | 0.7 ± 0.1 bc | 0.08 ± 0.04 bc |
| Rimon | 8.9 ± 1.9 b | 0.7 ± 0.2 bc | 0.08 ± 0.04 bc |
| Runner | 8.8 ± 1.7b | 0.7 ± 0.1 bc | 0.07 ± 0.04 bc |
| Virate | 7.1 ± 1.2b | 0.5 ± 0.1c | 0.05 ± 0.03 bc |
| Control | 25.1 ± 3.8a | 2.1 ± 0.4a | 0.3 ± 0.1ab |

* F = foliar application, S = soil application

Means within a column followed by the same letter are not significantly different from each other (SNK, P= 0.05).

Table 6. Effects of insecticides on citrus leaf miners on orange at Merti (Abadisca farm) in 2005 (MARC, 2006).

| Treatment | Infestation(%) | No. of mines | No. leaf miner larvae /leaf |
|---|---|---|---|
| Dimethoate | 20.5 ± 2.7a | 1.8 ±1.3a | 0.5 ± 0.1ab |
| Karate | 11.6 ± 2.5 ab | 1.2 ± 0.3ab | 0.1 ± 0.0c |
| Baythroid | 11.3 ± 2.6ab | 1.2 ± 0.3ab | 0.1 ± 0.0c |
| Pollo | 17.3 ± 2.3ab | 1.7 ± 0.2ab | 0.4 ± 0.1bc |
| Vertimec (F) | 8.4 ± 1.9 b | 1.0 ± 0.2 b | 0.1 ± 0.0c |
| Vertimec (S) | 19.0 ± 1.3a | 2.4 ± 0.2a | 0.9 ± 0.2a |
| Vertimec (F+S) | 12.4 ± 3.0 ab | 1.3 ± 0.3ab | 0.1 ± 0.1c |
| Actara | 22.6 ± 3.4 a | 2.3 ± 0.3 a | 0.4 ± 0.2bc |
| Rimon | 18.3 ± 2.5ab | 1.7 ± 0.2 ab | 0.3 ± 0.2bc |
| Runner | 15.9 ± 3.2ab | 1.6 ± 0.3ab | 0.2 ± 0.1bc |
| Virate | 15.4 ± 1.9ab | 1.5 ± 0.2ab | 0.1 ± 0.0c |
| Control | 14.2 ± 2.5ab | 1.5 ± 0.3 ab | 0.4 ± 0.2bc |

* F = foliar application, S = soil application

Means within a column followed by the same letter are not significantly different from each other (SNK, P= 0.05).

## Management of citrus thrips

Occasionally high levels of citrus thrips damage were observed at UAAIE and attempts were made to screen effective insecticides at Merti farm. In 2004, 11 insecticides were sprayed on orange trees. However, the populations of the thrips were low and no significant difference could be discerned between the insecticide treated and the untreated check. Future works on citrus thrips management should focus recording and promoting biological control agents, population dynamics study, and other IPM techniques.

## Integrated pest management on citrus thrips and leaf miner

According to PPRC (2006), an observation was conducted at Merti, Abadiska farm to evaluate integration of some new tactics, which include the use of cover crops, mulch, Success Bait, entomopathogens, and neem. Buckwheat and grass straw were used as a cover crop and mulching, respectively, to support the build up of natural enemies. *Beauveria bassiana* PPRC 56, an isolate obtained from *Pachnoda interrupta* in North Shoa was sprayed at the concentration of 1 x 115 in 250 l/ha on the outer canopy of the citrus trees. Success Bait which was found to be effective against the fruit flies, neem oil and petroleum oil (white oil) for general fruit pests including red scale, thrips, and miners were applied in November 2004. Monitoring of the population of citrus thrips and leaf miners and percentage of infestation were carried out every month during the peak season (starting October 2004). Hundred orange fruits per orchard were assessed after the petal fall and the percentage-damaged fruits were determined. Differences were observed among the various treatments. The cover crop (buckwheat) and mulching (grass straw) treatments minimised damage by pests. Following these promising results the enterprise is enlarging the area under these combinations of control methods. Currently, UAAIE has allocated 1.5 ha citrus area as a model site in Tibila farm for IPM component tests.

## Gap analysis

Although much has been done in documenting insect pests of fruit crops, most of the list comes from citrus, which is also incomplete. In addition, there are very few studies on natural enemies and extent of damages.

Most of the information we have is outdated. In addition, the growing of new crops, for example apple, and expansion of existing once necessitates for investigations and updating of the statuses of the pests.

There are very few researchers and experts working on fruit pests. There is no centre or an institution, which has been building excellence in researches on pests of fruit crops.

There is no continuity in the research undertakings of pests of fruit crops. Exemplary studies on red scale, earlier studies on documentation of the pests of fruit crops and attempts to introduce natural enemies did not continue.

There are few studies on IPM of fruit pests in Ethiopia. Studies on the management of fruit pests are dominated by the use of synthetic chemicals and studies on new management methods of fruit crop pests are lacking. Most of the management researches address the commercial farms and small-scale producers are neglected.

Most of the studies have not addressed the economics of protection. They have not considered the compliance of the method to be introduced with the current global trend of good agricultural practices (GAP) to enable the country export its produces to the international market.

Fruit research, in Ethiopia, linkage to international institutes is weak.

## Future

Periodic survey of fruit pests and their enemies should be conducted. Introduction of new pest species and change in status of the existing pests is probable. Survey and monitoring studies should be well planned to confer detailed information including the distribution of the pests, their economic importance in terms of extent of damage and date of observation. Records of natural enemies need to be accompanied with estimates in the levels of control excreted on the pest.

Research should give due emphasis for the management of fruit flies including the newly introduced species *Bactrocera invadens*, false codling moth, citrus leaf miner, citrus woolly whiteflies and the apple woolly aphid. Ecological studies on the newly emerging insect pests are mandatory future research undertakings.

Building the human capacity in fruit crops protection research should be given the highest emphasis. The little information we have in this sector compared to the others is mainly due to limited number of researchers' involvement. The research system should encourage these researches by allocating adequate resources. The research and education system should double efforts to improve the research undertaking capacity of the country by improving facilities for research, producing capable experts in the area of fruit crop protection and building centres of excellence.

Research on management of fruit crop pests should focus on integrated pest management (IPM). The commercial fruit farms mainly depend on synthetic pesticides to combat the various pests. The appearance of some pests as a major problem could be as a result of misuse of pesticides. It is known that many pests of fruit crops are controlled by natural enemies and indiscriminate use of pesticides will result in the decline population of enemies thereby resulting change of the pest status. Development of resistance to pesticides is another danger associated with the misuse and abuse of pesticides. Fruit crop pests are too many and pests cannot be effectively controlled by a single method. The research undertakings should focus on the integration of available technologies and inclusion of new components. The future fruit pest IPM mainly should include biological control, biopesticides, plant products, attractants, pheromones, and other emerging new technologies with soft synthetic pesticides. Researchers involved in biological control programs should aim at identifying efficient predators and parasitoids, which could be used against the major pests. The current use of pesticides should be evaluated in light of human and environmental health and acceptance of fruit produces in the world market. Researches should be initiated on exploring, collecting and identifying insect pathogens throughout the country to develop bio-pesticides.

Research need to address fruit crop protection problems of small-scale farmers.

Periodic training of producers on the management of fruit pests and proper and safe use of pesticides is necessary.

There are many organisations working on fruit pest problems in the world and there is a need to establish net works with regional and international research and development organisations working on fruit crop protection.

Appendix 1. List of insect pests recorded on fruit crops in Ethiopia.

| Scientific name | Common name | Crops attacked | Status | Ref. |
|---|---|---|---|---|
| **Acarina** | | | | |
| **Eriophyidae** | | | | |
| *Aceria sheldoni* (Ewing) | Citrus bud mite | Citrus, | unknown | 13 |
| *Eriophyes* sp. | Silver mite | Citrus | minor | 13 |
| *Eriophyes* sp. | Grape mite | Grape | unknown | 13 |
| *Phyllocuptruta* sp. | Citrus rust mite | Citrus | minor | 13 |
| **Tarsonemidae** | | | | |
| *Anychus latus* (C. & and F.) | Papaya mite | Papaya | unknown | 13* |
| **Tetranychidae** | | | | |
| *Eutetranychus anneckei* (Meyer) | Red citrus mite | Citrus, papaya | sporadic | 13 |
| *E. orintealis* (Klein) | Oriental mite | Citrus, pumpkin, fig | unknown | 13 |
| *E. pantopus* (Berl.) | Sudan citrus mite | Citrus, papaya | unknown | 13 |
| *Oligonychus vitis* (Zacher and Shehata) | Grape spider mite | Grape | unknown | 13 |
| *Tetranychus cinnabarinus* (Boisduval) | Red spider mite | Citrus | unknown | 13 |
| **Orthoptera** | | | | |
| **Tettigonidae** | | | | |
| *Eugaster aereus* (Sjostedt) | Strawberry grasshopper | Strawberry | unknown | 13* |
| **Pyrgomorphidae** | | | | |
| *Phymateus pulcherimus* (I. Bolivar) | Bush locust | Apple, citrus, fig, mango, olive, pomegranate, papaya, strawberry | unknown | 13 |
| *Phymateus viridipes* (stal) | Bush locust | Apple, citrus, fig, mango, olive, pomegranate, papaya, strawberry | unknown | 13 |
| **Acrididae** | | | | |
| *Schistocerca gregaria* (Forskal) | Desert locust | All crops | sporadic | 13 |
| **Homoptera** | | | | |
| **Aleyrodidae** | | | | |
| *Aleurothrixus floccocus* (Maskell) | Citrus woolly whitefly | Citrus | major | 4 |
| **Diaspididae** | | | | |
| *Aonidiella aurantii* (Maskell) | California red scale | Citrus, grape, macadamia | major | 12, 13 |

Appendix 1. Contd.

| Scientific name | Common name | Crops attacked | Status | Ref. |
|---|---|---|---|---|
| *A. orientalis* (Newstead) | Oriental scale | Avocado, citrus, macadamia, palms | minor | 13 |
| *Aspidiotus destructor* (Signoret) | Coconut scale | Avocado, banana, palms, mango olive | unknown | 13 |
| *A. nerii (*Bouche) | Oleander scale | Citrus, mango, olive, palms | unknown | 13 |
| *Chrysomphalus aonidum* (Linnaeus) | | Banana, citrus, fig, mango, palms | minor | |
| *C. dictyospermi* (Morgan) | Orange scale | Citrus, fig, olive, palms | unknown | 12, 13* |
| *C. pinnulifer* Maskell | Palm scale | palms | unknown | 13* |
| *Hemiberlesia lantaniae* (Signoret) | Lantania scale | Apricot, citrus, grape, guava, loquat, mango, mulberry | minor | 13 |
| *Ischnaspia longirostris* (Signoret) | Black thread scale | Citrus, mango, palms, annona | minor | 13 |
| *Lepidosaphes beckii* (Newman) | Mussel scale | Citrus, fig, olive | minor | 13 |
| *L. ulmi* (Linnaeus) | Oyster shell scale | Olive | unknown | 13 |
| *Neoselenaspidus silvaticus* (Lindinger) | Great red scale | Citrus, palms | minor | 13 |
| *Parlatoria zizyphus* (Lucas) | Black scale | Citrus | major | 12, 13 |
| *P. blanchardi* (Targioni-Tozzetti) | Date palm scale | palms | minor | 13 |
| *Selenaspidus articulatus* (Morgan) | | Citrus, Kei apple, olive, palms | minor | 13 |
| **Coccidae** | | | | |
| *Ceroplastes rusci* (Linnaeus) | Fig wax scale | Citrus, fig | minor | 13 |
| *Coccus alpinus* De Lotto | Soft green scale | Guava | unknown | 13 |
| *C. elongaues* (Signoret) | Soft long scale | Bullocks heart/custard apple | unkown | 13 |
| *C. hesperidium* (Linnaeus) | Soft brown scale | Citrus, mango, guava, fig, papaya | minor | 13 |
| *C. viridis* (Green) | Green scale | Citrus, guava, mango, | unknown | 13 |
| *Parasaissetia nigra* (Nietner) | Black helmet scale | Apple, guava, custard apple | minor | 13 |
| *Saissetia coffea* (Walker) | Helmet Scale | Citrus, fig | minor | 13 |
| *S . cuneiformis* Leon. | Cuneiform scale | Olive | unknown | 13* |

Appendix 1. Cont'd.

| Scientific name | Common name | Crops attacked | Status | Ref. |
|---|---|---|---|---|
| *S. oleae* (Bernard) | Olive scale | Citrus, olive | sporadic | 13 |
| *S. somereni* (Newstand) | Somereni scale | Mango | unknown | 13 |
| **Pseudococcidae** | | | | |
| *Dysmicoccus brevipes* Cockerell | Pineapple mealybug | Banana, citrus, pineapple, palms | unknown | 12 |
| *Ferrisia virgata* (Cockerell) | Striped mealybug | Citrus, banana, Bullocks heart/ custard apple | sporadic | 13 |
| *Planococcus citri* (Risso) | | Citrus, grape, banana, palms, coffee | unknown | 13 |
| **Margrodidae** | | | | |
| *Icerya purchasi* Maskell | Cottony cushion scale | Citrus | minor | 13 |
| **Cercopidae** | | | | |
| *Locris auripennis* (Distant) | Red spittle bug | Citrus | minor | 13 |
| **Tettigometridae** | | Citrus | | |
| *Hilda patruelis* Stal | Ground nut hopper | Citrus | | 13 |
| **Aphididae** | | | | |
| *Aphis craccivora* Koch | Groundnut aphid | Apple | unknown | 2, 13 |
| *A. gossypii* Glover | Cotton aphid | Citrus, water melon, Indian jujube, mango | unknown | 2, 13 |
| *Brachycaudus cardui* (Linnaeus) | Carduus aphid | plum | unknown | 13* |
| *Eriosoma langigerum* (Hausman) | Woolly aphid | Apple | unknown | 2, 13* |
| *Pentatrichopus fragaefolii* Coquerel | Strawberry aphid | Strawberry | unknown | 13* |
| *Toxoptera aurantii* (Boyer de Fonoscolombe) | Coffee aphid | Citrus, mango Koshim | unknown | 13 |
| *T. citricidus* (Kirkaldy) | Citrus aphid | Citrus, Kei apple | unknown | 2, 13 |
| **Triozidae** | | | | |
| *Trioza erytreae* Del Guerico | Citrus psyllid | citrus | major | 13 |
| **Heteroptera** | | | | |
| **Miridae** | | | | |
| *Helopeltis schoutedni* Reuter | Cotton helopeltis | Guava, mango | unknown | 13 |
| **Lygaiedae** | | | | |
| *Dieuches* sp. nr. *Africanus* (Distant) | Strawberry bug | Strawberry | unknown | 13 |
| *Spilostethus pandurus* (Scopoli) | Red bug | Grape | minor | 13 |

Appendix 1. Contd.

| Scientific name | Common name | Crops attacked | Status | Ref. |
|---|---|---|---|---|
| **Coreidae** | | | | |
| *Anoplocnemis curvipes* (Fabricius) | Giant twig wilter | Citrus , fig, mango | minor | 13 |
| *Cletus fuscescens* (Walker) | Cletus bug | Citrus | unknown | 13 |
| *Leptoglossus memebranaceus* (Fabricius) | Leaf-footed plant bug | Citrus, cucurbits | minor | 13 |
| **Tingidae** | | | | |
| *Pleurochila australis* (Distant) | Olive lace bug | Olive | minor | 13* |
| **Pentatomoiade** | | | | |
| Agonoscelis pubescens (Thunberg) | Cluster bugs | Citrus | minor | 13 |
| *Antestiopsis intricate* (Ghesquiere and Carayon) | Antestia bug | Citrus | unknown | 13 |
| *Calidea bohemani* (Stal) | Blue bug | Citrus | minor | 13 |
| *C. dudodecimpunctata* (Fabricius) | Blue bug | Citrus | minor | 13 |
| *Calidea nana* | Blue bug | Citrus | minor | 13 |
| *Cryptacrus comes form pinguis* (Germar) | Loquat bug | Loquat | unknown | 13 |
| *Halydicoris ventralis* (Dallas) | Citrus stink bug | Citrus | minor | 13 |
| *Sphaerocoris annulus* | Ringed bug | Citrus | unknown | 13 |
| **Thysanoptera** | | | | |
| **Thripidae** | | | | |
| Liothrips oleae (Costa) | Olive thrips | Olive | unknown | 13 |
| *Retithnips syriacus* (Mayet) | Castor thrips | Grape, papaya | unknown | 13 |
| *Scirtothrips aurantii* Faure | Citrus thrips | citrus | major | D |
| *S.* sp *mangiferae* Priesner | Mango thrips | peach | unknown | 13 |
| **Lepidoptera** | | | | |
| **Gracilliridae** | | | | |
| *Phyllocnistis citrella* Stainton | Citrus leaf miner | citrus | major | 13 |
| **Metarbelidae** | | | | |
| *Salagena irrorata* Le Cerf | Citrus borer | Citrus | unknown | 13* |
| **Totricidae** | | | | |
| *Cryptophelebia leucotereta* (Meyrick) | False codling moth | Avocado, citrus, Bullocks heart/custard apple | major | 13 |
| *Epichorista* sp. | Raspberry tortrix | Raspberry | unknown | 13 |
| *Lobesia botrana* (Schiffermuller) | Grape moth | Grape | unknown | 13 |
| **Lycanidae** | | | | |
| *Taracus grammicus Gosse_smith* | Zizyphus blue | | unknown | 13 |

Appendix 1. Contd.

| Scientific name | Common name | Crops attacked | Status | Ref. |
|---|---|---|---|---|
| **Papilionidae** | | | | |
| *Papilio dardanusi* Brown | Mocker swallowtail | Citrus | minor | 13 |
| *P. demodocus* | Orange dog | Citrus | minor | 13 |
| **Hesperiidae** | | | | |
| *Zophopetes dysmephila* (Trimen) | Palm skipper | palms | unknown | 13* |
| **Lasiocampidae** | | | | |
| *Nadiasa concave* Strand | Macadamia tent caterpillar | Macadamia | unknown | 13 |
| **Bombycidae** | | | | |
| *Ocinara ficicola* Westwood | Fig moth | Fig | minor | 13 |
| **Saturindae** | | | | |
| *Drepanoptera atbarina* Butler | Zizyphus silkworm | Indian jujube | unknown | 13* |
| **Sphingidae** | | **Citrus** | | |
| *Hippotion celerio* (Linnaeus) | Vine hawkmoth | Citrus, grape | minor | 13 |
| *Hyles (celerio) lineata* (Fabricius) | Silver stripped hawkmoth | Grape | minor | 13 |
| **Notodontidae** | | | | |
| *Desmeocraera* sp. nr. *Congoana Aurivillius* | Guava moth | Guava | unknown | 13 |
| **Arctiidae** | | | | |
| *Diacrisia investigatorum* (Karash) | Papaya tiger moth | Papaya | minor | 13 |
| *Syntomis alicia* Butler | Tomato tiger moth | Citrus | minor | 13 |
| **Noctuidae** | | | | |
| *Achaea castela* Guenee | Castor semi-lopper | Citrus | minor | 13 |
| *Calpe emarginata* | Fruit piercing moths | Citrus | sporadic | 13 |
| *C . hierogyhica* Saalm. | Fruit piercing moths | Citrus | sporadic | |
| *C. provocans* Walk. | Fruit piercing moths | Citrus | sporadic | 13 |
| *Ctenoplusia lirohirena* Guennee | Plusia worm | Fig | | 13 |
| *Eublemma olivacea* (Walker) | Fig worm | Fig | | 13 |
| *Heliothis armigera* (Hubner) | African bollworm | Strawberry | minor | 13 |
| *Othreis materna* (Linnaeus) | Fruit piercing moth | Citrus | sporadic | 13 |
| **Lymantridae** | | | | |
| *Euproctis dewitzi* | Apple tussockmoth | Apple | unknown | 13* |

Appendix 1. Contd.

| Scientific name | Common name | Crops attacked | Status | Ref. |
|---|---|---|---|---|
| **Diptera** | | | | |
| **Drosophilidae** | | | | |
| ?*Amiota (Erimia)* sp. | Citrus drosophilid | Citrus | uncertain | 13 |
| *Drosophila simulans* Start | Peach drosophilid | Peach | Minor | 13 |
| *Zaprionus vittiger* Coquillett | Citrus vinegar fly | Citrus, peach | uncertain | 13 |
| **Tephritidae** | | | | |
| *Carpomyia incomplete* (Becker) | Zizyphus fruit fly | Indian Jujube | unknown | 13* |
| *Ceratitis capitata* (Wiedman) | Mediterranean fruit fly | Citrus, guava, mango | major | 13 |
| *Ceratitis fasciventris* | | Mango | | 1 |
| *Dacus ciliatus* Loew | Lesser melon fly | Citrus, cucurbits | unknown | |
| *D. bivittatus cucumarius* Sack | Cucurbit fly | Papaya | minor | 13 |
| *D. oleae* (Gemelin) | Olea fly | Olive | common | 13* |
| *Bactrocera invadens* | Tephritid fruit fly | Mango, guava | major | 5 |
| **Hymenoptera** | | | | |
| **Vespae** | | | | |
| *Vespa orientalis* Linnaeus | Oriental wasp | Citrus, grape, palms | unknown | 13 |
| **Coleoptera** | | | | |
| **Apionidae** | | | | |
| *Apion* sp. | Black pod weevil | Peach | unknown | 13 |
| *Piezotrachelus microcephalus* Wagner | Peach weevil | Peach | unknown | 13* |
| **Chrysomelidae** | | | | |
| *Aphtona marshalli* Jacoby | Bean flea bettle | Peach | unknown | 13 |
| *Dactylispa contribulis* Weise | Gibbera hispid | Gibbera | unknown | 13 |
| *D. hirsute* Gerstaecker | Peach hispid | Gibbera, peach | unknown | 13 |
| *Haltica pyritosa* Erichson | Linseed flea beetle | Grape | unknown | 13 |
| *Megalopgnatha abyssinica* Jacoby | Peach beetle | Peach | unknown | 13 |
| *M. aenea* Laboissiere | Acacia beetle | Avocado, peach | unknown | 13 |
| *Megalopgnatha viridipennis* Weise | Peach green beetle | Peach | unknown | 13 |
| **Lagriidae** | | | | |
| *Lagria viliosa* Fabricius | Metallic leaf beetle | Fig | minor | 13 |
| **Scarbaeidae** | | | | |
| *Amaurina lunicollis* Kolbe | Amaurina beetle | Citrus | unknown | 13 |
| *Anomaa tendinosa* echo Kolbe | Grape scarab | Grape | unknown | 13 |
| *Pachnoda abyssinica* Blanford | Yellow rose chafer | Citrus | unknown | 13 |

Appendix 1. Contd.

| Scientific name | Common name | Crops attacked | Status | Ref. |
|---|---|---|---|---|
| *P. peregerina* Kolbe | Mango chafer | Mango | unknown | 13 |
| *P. massaje* Gestro | Yellow headed chafer | Mango | unknown | 13 |
| *Rhabdotis sobrina* Gory and Perch | Citrus chafer | Citrus | minor | 13 |
| **Bostrychidae** | | | | 13 |
| *Apate monachus* Fabricius | Black borers | Citrus, grape, guava, mango, palms | sporadic | 13 |
| *A. indistincta* Murray | Black borers | Guava | sporadic | 13 |
| **Bupretsidae** | | | | 13 |
| *Chrysobothris dorsata* Fabricius | Chat borer | Fig | minor | 13 |
| *Julodis caillaudi* (Latr.) | Juloids beetle | Palms | unknown | 13* |
| **Cerambycidae** | | | | |
| *Phryneta spinator* (Fabricius) | Fig borer | Fig | unknown | 13* |
| *Phrynotopsis variegata* (Reiche) | Fig borer | Fig | unknown | 13* |
| *Sthenias cylindrator* Fabricius | Grape lamiid | Grape | unknown | 13* |
| **Curculionoidae** | | | | |
| *Amblyrhinus brunneus* Hustache | Almond weevil | Almonds | unknown | 13* |
| *Aplemonus zizyphii* Marshall | Zizyphus weevil | Indian jujube | unknown | 13* |
| *Myllocerus* sp | Myllocerus weevil | Almond weevil | unknown | 13* |
| *Rhynocophorus phoenicis* (Fabricius) | Palm weevil | Palms | unknown | 13* |
| **Scolytidae** | | | | 13* |
| *Coccotrypes dactyliperda* Fabricius | Dum nut borer | Ivory nut | unknown | 13* |

* = pests were first recorded from Eritrea, D = Difabachew Belay, pers.com.

Appendix 2. Production of mango fruits at Upper Awash Agro-Industry Enterprise and the extent of fruit yield loss caused by fruit flies (Birtukan, 2006).

| Mango varieties | Infested fruits (%) | No. fruits checked | No. of trees/ha | No. fruits/ tree | Fruit weight (kg) | Fruit yield (kg/ha) | Yield loss (kg/ha) | Average selling price | Monetary loss (birr/ha) |
|---|---|---|---|---|---|---|---|---|---|
| Dodo | 20.5±0.02a | 1551 | 156 | 351.5 | 0.296± 0.017 | 16230.9 | 3327.3 | 3.15 | 11481.1 |
| Tommy Atkins | 14.6±0.02a b | 1180 | 156 | 380.5 | 0.321± 0.018 | 19053.9 | 2781.9 | 3.15 | 8762.9 |
| Keitt | 14.2±0.03a b | 542 | 156 | 155.0 | 0.402± 0.035 | 9720.4 | 1380.3 | 3.15 | 4347.9 |
| Abadir (local) | 12.4 ± 0.01b | 35903 | 156 | 1301.7 | 0.158± 0.003 | 32083.1 | 3978.3 | 1.05 | 4177.2 |
| Kent | 3.9 ± 0.01c | 1108 | 156 | 460.0 | 0.329± 0.026 | 23609 | 920.8 | 3.15 | 2900.4 |

Means followed by the same letter for percentage number of fruits infested are not significantly different from each other at 5% probability (Tukey's), ± standard error of the mean, CV = 6 %.

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# Research on Insect Pests of Oil Crops in Ethiopia

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## Introduction

Noug or Nigerseed (*Guizotia abyssinica*), sesame (*Sesame indicum*), Groundnut (*Arachis hypogia*), safflower, (*Carthamus tinctorius*), linseed, (*Linum usitatissimum*) and gomenzer/ Ethiopian mustard, (*Brassica carinata*) are important oil crops grown by commercial farms and small-scale producers both for local consumption and export. Most of the oilseeds are primarily produced for oil extraction, while groundnut is used as a source of oil and for confectionary purposes. Sesame production is mostly export targeted and the oil is known for its high quality among vegetable oils, it contains several lignins providing very long shelf life and stable characteristics (IAR, 1993).

According to CSA (2006), noug is the first ranking oil crop both in terms of area coverage and production. It accounted for about 43.5% of the total area and production, while linseed and sesame accounted for 30.41 and 16.5%, respectively of the total area and production volume of oilseeds in the country (Table 1). As to the export volume and value, sesame ranks first with 238,307 and 208,919 tons and foreign exchange value of 198,425,000 and 170,697,000 USD for the year 2005/06 and 2006/07, respectively (Table 2). Nigerseed, linseed, castor bean and groundnut ranked second, third and fourth in export volume and value (Table 2).

Although, sesame grows in almost all regions of the country, it is a well-established cash crop in the north and northwestern plains adjacent to the Sudan (Seegler, 1983; Yebio, 1985). Groundnut is the second important lowland oilseed of warm climates, although it is relatively new crop to Ethiopia (Yebio, 1983). Eastern Hararghe produces substantial amount of groundnut, while some other lowland areas of Gamo Goffa, Ilubabor, Gojam, Shewa, Wollo, and Wollega have also of immense potential (Yebio, 1983; Adugna, 1991; Getinet and Nigussie, 1992). For the last eight years, the area covered by sesame and its total production has tremendously increased due to its attractive prices in the export market (Tadele, 2005). Noug is exclusively grown by small-scale

farmers on clay soils that are difficult for other crops to survive, although its productivity on clay soils is low. Mustard, sunflower and safflower are also produced as sources of edible oil by small scale farmers.

Some of the major problems of oil crop production in Ethiopia are lack of improved seed and production packages, insect pests, diseases, and weeds (Adugna, 1991; Gemechu and Bulcha, 1992). Results of research on oil crop protection have been reviewed by different authors in the past (Kemal *et al*., 1986; Alemayehu and Ababu, 1992; Tadesse and Bayeh, 1992). However, these information have not been put together to be easily accessible to users. Moreover, results of research conducted in the last two decades have not been reviewed. The purpose of this review is to compile the available information in one document and make accessible to users.

Table 1. Area coverage, production and yields of oil crops in 2004 and 2005.

| Crop | Area ( ha) | | Production ('000 t) | | Yield (t/ha) | |
|---|---|---|---|---|---|---|
| | **2004** | **2005** | **2004** | **2005** | **2004** | **2005** |
| Noug | 281.72 | 358.83 | 1,189.95 | 1,872.14 | 0.422 | 0.522 |
| Linseed | 142.90 | 250.7 | 773.63 | 1,518.64 | 0.541 | 0.606 |
| Sesame | 91.53 | 136.22 | 614.62 | 1,153.88 | 0.672 | 0.847 |
| Brassica | 26.02 | 41.88 | 292.84 | 358.38 | 1.125 | 0.856 |
| Groundnut | 20.217 | 27.08 | 207.15 | 290.53 | 1.025 | 1.073 |
| Safflower | 8.40 | 9.72 | 50.43 | 70.39 | 0.600 | 0.725 |

Source: CSA 2006

Table 2. The volume and value of oilseed commodity exported during 2005/2006 and 2006/2007 (July to June) ( MoARD, unpublished data).

| Oil seeds | July 2005– June 2006 | | | | July 2006– June 2007 | | | | % change | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Volume* | Value* | % share | | Volume | Value | % share | | | |
| | | | Volum | Value | | | Volum | Value | Volum | Value |
| Sesame | 238307 | 198425 | 90.5 | 94.6 | 208919 | 170697 | 88.6 | 90.8 | -12.3 | -14.0 |
| Niger | 21790 | 9883 | 8.3 | 4.7 | 14056 | 7694 | 6.0 | 4.1 | -35.5 | -22.1 |
| Linseed | 1278 | 641 | 0.5 | 0.3 | 354 | 241 | 0.2 | 0.1 | -72.3 | -62.4 |
| Caster | 1260 | 493 | 0.5 | 0.2 | 320 | 114 | 0.1 | 0.1 | -74.6 | -76.9 |
| Groundnut | 199 | 151 | 0.1 | 0.1 | 138 | 121 | 0.1 | 0.1 | -30.7 | -19.9 |
| Pumpkin seed | 193 | 149 | 0.1 | 0.1 | | | 0.0 | 0.0 | -100.0 | -100.0 |
| Cotton | 183 | 28 | 0.1 | 0 | 707 | 110 | 0.3 | 0.1 | -286.3 | 292.9 |
| Sunflower | 3 | 1 | 0 | 0 | 1 | 1 | 0.0 | 0.0 | -66.7 | 0.0 |
| Rapeseed | 1 | 0.2 | 0 | 0 | 500 | 399 | 0.2 | 0.2 | | |
| Unidentified | 38.03 | 15.04 | 0 | 0 | 10795 | 8626 | 4.6 | 4.6 | | |
| Grand total | 263251 | 209786 | 100 | 100 | 235790 | 188003 | 100.0 | 100.0 | -10.6 | -10.4 |

*Volume in tons and value in 000 USD.

# Research findings

## Insect pests recorded on noug

Earlier studies indicated that noug flower thrips, noug fly, and crickets were potentially important pests on noug in Ethiopia (Kemal *et al*. 1986). Latter surveys conducted in different areas (between Ambo and Gedo, Holetta and Adaa Berga, Wolkite, and Goha Tsion) showed that the black pollen beetle (*Meligethes* sp.), noug flies (*Dioxyna* and *Eutretosoma* spp.) and the black thrips (*Haplothrips* sp.) were the major insect pests of noug (Table 3). Among several insects recorded in the northwest Ethiopia, only a leaf miner was reported to be important. The parasitoids in the family Eulophidae *(Aprostocetus* and *Entendon* spp.), Eupelmidae *(Eupelmus* sp.) and Eurytomidae *(Euritoma* sp.) were recovered from flower heads infested with noug flies and black pollen beetles (IAR, 1990; 1992; 1993). The leaf miner was found to be parasitized by Ichneumonid wasps in Adet area (ARARI, 2000; 2002).

## Sesame and groundnut pests

Insect and mite pests recorded on sesame and groundnuts are presented (Table 4). In the past termites were reported to be important on both sesame and groundnut only in Wollega area (IAR, 1985b; 1986c; Kemal *et al.*, 1986). Now the problem has become expanded to other areas such as Hararghe, Gamo Goffa and the Middle Awash. Sesame seed bug (*Elasmolomus sordidus*) is a serious pest in the northwest (Geremew et. al., 2005), while jassids, the African bollworm and thrips are becoming important pests of groundnut in all areas where it is grown (Table 5). In storages, the Tropical warehouse moth and different species of beetles were reported to be important on both crops (Tables 4 and 5).

## Linseed insect pests

About four species of insects have been recorded attacking linseeds in Ethiopia. These are the flea beetle (*Halitica pyritosa*), blue bug (*Calidea duodecimpunctata*), the African bollworm and golden plusia (*Diachrysia arichalcea*). The African bollworm is the most common species in many places of linseed growing areas of the country, while others are sporadic and occur in small numbers (Table 6).

Table 3. Insect pests recorded on noug in Ethiopia.

| Scientific name | Common name | Status | References |
|---|---|---|---|
| **Coleoptera** | | | |
| **Chrysomelidae** | | | |
| *Decaria abdominalis* Jac. | Chrysomelid beetle | Minor | 24 |
| **Curculionidae** | | | |
| Piezotrachelus *milkoi* Balfour-Browne | Apionid weevil | Minor | 24 |
| **Meloidae** | | | |
| **Meligethes** sp. | Black pollen beetle | Major | 24 |
| **Diptera** | | | |
| **Cecidomidae** | | | |
| *Dioxyna sorercula* Wiedeman | Noug fly | Major | 25 |
| **Tephritidae** | | | |
| *Eutretosoma* sp. | Noug fly | Major | 17, 18 |
| **Heteroptera** | | | |
| **Miridae** | | | |
| *Tayloriygus pallidus* (Blanch) | Mirid bug | Minor | 12 |
| **Homoptera** | | | |
| **Aphididae** | | | |
| *Aphis spiracolae* | Citrus aphid | Miner | 24 |
| **Lepidoptera** | | | |
| **Noctuidae** | | | |
| *Helicoverpa armigera* Hub. | African bollworm | Minor | 31 |
| *Chrysodeixis circumflexa* L. | Plusia worm | Minor | 12 |
| *Perigea* conducta Walk | - | Minor | 9 |
| *Trichoplusia orichalcea* (Fabricius) | Golden plusia | Minor | 9 |
| *Trichothyrea mulsanti* (Guerin) | - | Minor | 23, 25 |
| **Orthoptera** | | | |
| **Grylidae** | | | |
| *Gryllus bimaculatus* | Crickets | | 24 |
| *Medicogryllus* spp. | Crickets | Major | 24 |
| **Thysanoptera** | | | |
| **Phlocothripidae** | | | |
| *Happlothrips articulosus* (Bagnall) | Noug flower thrips | Major | 24, 26 |
| **Thripidae** | | | |
| *Synaptothrips* sp. | Thrips | Minor | 23, 25 |

Table 4. Insect and mite pests recorded on sesame in Ethiopia.

| Scientific name | Common name | Status | Ref. |
|---|---|---|---|
| **Acarina** | | | |
| **Tarsonemidae** | | | |
| *Polyphagotarsonemus latus* (Banks) | Yellow tea mite | Minor/ moderate | 2 |
| **Coleoptera** | | | |
| **Chrysomelidae** | | | |
| *Podagracia* spp. (Jacoby) | Flea beetle | Major | 2, 3, 12 |
| **Silvanidae** | | | |
| *Oryzaephilus surinamensis* | Saw toothed grain weevil | Minor | |
| **Tenebrionidae** | | | |
| *Tribolium castaneum* | Red flour beetle | Minor | 2, 6 |
| **Elateridae** | | | |
| *Conoderus vespertinus* F | | Minor | 2, 6 |
| **Meloidae** | | | |
| *Epicauta albovittata* (Gestro) | Stripped blister beetle | Minor | 2, 6 |
| *Gonocephalum simplex* (Fabicius) | Dusty brown beetle | Minor | 2, 6 |
| **Diptera** | | | |
| **Cecidomyidae** | | | |
| *Asphondylia sesami* (Felt.) | Sesame gall midge | Minor | 2 |
| **Heteroptera** | | | |
| **Lygaeidae** | | | |
| *Elasmolomus sordidus* (Fabicius) | Sesame seed bug | Major | 5, 6, 14 |
| **Pentatomidae** | | | |
| *Agonoscelis pubescens* (Thunberg) | Cluster bug | Minor/ moderate | 6 |
| *Nezara viridula* (L.) | Green stink bug | Minor/ moderate | 6 |
| **Homoptera** | | | |
| **Aphididae** | | | |
| *Myzus persicae* (Sluzer) | Green peach aphid | Moderate/ major | 2, 6 |
| **Cicadellidae** | | | |
| *Empoasca spp.* (Jacobi) | Jassid | Minor /moderate | 2, 6 |
| **Lepidoptera**<br>**Gelechidae**<br>*Ephestia cautella* Wlk | Tropical ware house moth | Major | |
| **Noctuidae** | | | |
| *Helicoverpa armigera* (Hubner) | African bollworm | Minor | 2, 6 |
| **Pyralidae** | | | |
| *Antigastra catalaunalis* (Duponchel) | Sesame webworm | Moderate/ major | 2, 6 |
| **Orthoptera** | | | |
| **Acrididae** | | | |
| *Aiolopus simulatrix* (Walker) | Grasshopper | Minor/ moderate | 7, 12 |

Table 5. Insect pests recorded on groundnut in Ethiopia.

| Scientific name | Common name | Status | Ref. |
|---|---|---|---|
| **Coleoptera** | | | |
| **Meloidae** | | | |
| *Epicauta albovittata* (Gestro) | Stripped blister beetle | Moderate to major | 2, 6, 24 |
| *Mylabris* spp. (Reiche) | Pollen beetle | Moderate to major | 2, 6, 24 |
| **Tenebrionidae** | | | |
| *Gonocephalum simplex* (Fabicius) | Dusty brown beetle | Minor | 2, 6, 24 |
| **Homoptera** | | | |
| **Aleyrodidae** | | | |
| *Bemisia tabaci* (Gennadius) | Whitefly | Minor to moderate | 2, 6, 24 |
| **Aphididae** | | | |
| *Aphis craccivora* (Koch) | Groundnut aphid | Moderate to major | 2, 6, 11, 24 |
| **Cicadellidae** | | | |
| *Empoasca spp.*(Jacobi) | Jassid | Minor to moderate | 2, 6, 24 |
| **Heteroptera** | | | |
| **Pentatomidae** | | | |
| *Nezara viridula* (L.) | Green stink bug | Minor | 2, 6, 24 |
| **Isoptera** | | | |
| **Termitidae** | | | |
| *Odontotermes anceps* (Sjostedt) | Termite | Moderate to major | 6, 7, 12, |
| **Lepidoptera** | | | |
| **Noctuidae** | | | |
| *Helicoverpa armigera* | African bollworm | Moderate to major | 2, 16, 24 |
| *Spodoptera littoralis* | Cotton leaf worm | Moderate to major | 2, 12, 16 |
| *Spodoptera exuga* | Lesser armyworm | Moderate to major | 2, 11 |
| **Orthoptera** | | | |
| **Acrididae** | | | |
| *Aiolopus simulatrix* (Walker) | Grasshopper | Minor to moderate | 2, 6, 16 |
| **Thysanoptera** | | | |
| **Thripidae** | | | |
| *Thrips* spp. | Thrips | Minor to moderate | 12 |

Table 6. Linseed insect pests recorded in Ethiopia (after IAR 1992).

| Scientific name | Common name | Status |
|---|---|---|
| **Coleoptera** | | |
| **Chrysomelida** | | |
| *Halitica pyritosa* | Flea beetle | Miner |
| **Hetroptera** | | |
| **Pentatomidae** | | |
| *Calidea duodecimpunctata* | Blue bug | Miner |
| **Lepidoptera** | | |
| **Noctuidae** | | |
| *Diachrysia arichalcea* | Golden plusia | Miner |
| *Helicoverpa armigera* | African bollworm | Major |

## Insect pests of mustard, safflower and sunflower

The insect pests recorded on these crops are presented in Tables 7, 8 and 9. Flea beetles, golden plusia, and cabbage white are important in mustard, whereas the African bollworm is important in safflower and sunflower (Kemal *et al*., 1986).

Table 7. Insect pests recorded on mustard in Ethiopia.

| Scientific name | Common name | Status | References |
|---|---|---|---|
| *Coleoptera* | | | |
| **Curculiondae** | | | |
| *Lixus lartro* Marshall | Cabbage weevil | Uncertain | 10, 24 |
| **Chrysomelidae** | | | |
| *Phyllotreta meshonana* Jacoby | Cabbage flea beetle | Major | 5, 12, 24, 29 |
| *Phyllotreta weisei* Jacoby | Cabbage flea beetle | Major | 24, 29 |
| **Meloidae** | | | |
| *Mylabris* spp. | Pollen beetle | Uncertain | 24, 27 |
| **Diptera** | | | |
| **Agromyzidae** | | | |
| *Liriomyza brassicae* (Riley) | Cabbage leaf miner | Minor | 5, 24 |
| **Heteroptera** | | | |
| **Pentatomidae** | | | |
| *Bagrada hilaris* (Burmeister) | Bagrada bug | Uncertain | 5 |
| **Homoptera** | | | |
| **Aphididae** | | | |
| *Brevicoryne brassicae* (L) | Cabbage aphid | Major | 5, 6, , 25 |
| *Lipaphis erysimi* (Kalternbach) | Cabbage aphid | Minor | 5, 6, , 25 |

Table 7. Contd.

| Scientific name | Common name | Status | References |
|---|---|---|---|
| **Hymenoptera** | | | |
| **Tenthredinidae** | | | |
| *Athalia s. schweifurthi* Konow | Cabbage sawfly | Minor | 12 |
| **Lepidoptera** | | | |
| **Noctuidae** | | | |
| *Trichoplusia orichalcea* (Fabrius) | Golden plusia | Sporadic | 5 |
| **Pieridae** | | | |
| *Pieriss brassicoides* Guerin-Menville | Cabbage white | Sporadic | 6, 11, 24, 27 |
| **Plutellidae** | | | |
| *Plutella xylostella* (Linnoeus) | Diamondback moth | Major | 5, 24 |

Table 8. Insect pests recorded on safflower in Ethiopia.

| Scientific name | Common name | Status | References |
|---|---|---|---|
| **Diptera** | | | |
| **Tephritidae** | | | |
| *Acanthiophilus helianthi* (Rossi) | Safflower fly | Minor | 24 |
| **Homoptera** | | | |
| **Aphididae** | | | |
| *Aphis craccivora* (Koch) | Groundnut aphid | Moderate/ major | A* |
| *Brachyunguis pseudocardui* (Theob.) | - | Minor | 8 |
| *Capitophorus elaegani* (Del Guericio) | Artichoke aphid | Minor | 24 |
| *Dactynotus compositae* Theob. | Safflower aphid | Minor | 10, 11, 24 |
| **Lepidoptera** | | | |
| **Noctuidae** | | | |
| *Heliothis armigera* Hubner | African bollworm | Major | 24 |
| *Heliothis nubigera H.S.* | - | Minor | 9 |
| *Heliothis peltigera* (Schiffermulle) | Safflower budworm | Minor | 24 |

* identified by the senior author

Table 9. Insect pests recorded on sunflower in Ethiopia.

| Scientific name | Common name | Status | References |
|---|---|---|---|
| **Coleoptera** | | | |
| **Cetonidae** | | | |
| *Trichothyrea mulsanti* (Guerin) | - | Minor | 24 |
| **Cerambycidae** | | | |
| *Haltica pyritosa* (Erichson) | Linseed flea beetle | Major | 5, 6, 24 |
| **Chrysomelidae** | | | |
| *Erlangerius niger* (Weise) | Black tef beetles | Minor | 6 |
| **Coccinellidae** | | | |
| *Epilachna* spp. | Epilachna beetle | Minor | 24 |
| **Curculionidae** | | | |
| *Lixus latro* (Marshall) | Cabbage weevil | Minor | 6, 24 |
| **Lagriidae** | | | |
| *Lagria villosa* (Fabricius) | Metallic leaf beetle | Minor | |
| *Chrysolagria* spp. | False blister beetle | Minor | 5, 6, 24 |
| **Nitidulidae** | | | |
| *Carpophilus dimitiatus* (F.) | Corn sap beetle | Minor | 24 |
| **Scarabaeidae** | | | |
| *Leucocelis* spp. | Scarab beetles | Minor | 24 |
| *Pacnoda crassa fairmairei* (Raffray) | - | Minor | 24 |
| **Tenebrionidae** | | | |
| *Tenebriodes mauritanicus* (L.) | - | Minor | 24 |
| **Hetroptera** | | | |
| **Coreidae** | | | |
| *Anoplocnemis curvipes* (Fabricius) | Giant twig wilteer | Minor | 5, 24 |
| *Cletus* spp. | Cletus bug | Minor | 24 |
| *Triconotolema caelestina* (Klug) | - | Minor | 24 |
| **Lygaeidae** | | | |
| *Lygaeus negus* (Distant) | - | Minor | 24 |
| *Nysius senecoinis abyssinicus* (Schmitz) | Wheat bug | Minor | 24 |
| *Oxycarenus hyaalinipennis* (Costa) | Cotton seed bug | Minor | 24 |
| *O. zavattarii* (Mancini) | - | Minor | |
| *Spilostethus pandurus* (Scopoli) | Red bug | Minor | 24 |
| **Rhopalidae** | | | |
| *Liorhyssus hyalinus* (Fabricius) | Scentless plant bug | Minor | 24 |

Table 9. Contd.

| Scientific name | Common name | Status | References |
|---|---|---|---|
| **Pentatomidae** | | | |
| *Agonoselis pubescens* (Thunberg) | Cluster bug | Minor | 24 |
| *Nezara viridula* (Linnaeus) | Green stink bug | Minor | 5, 24 |
| **Homoptera** | | | |
| **Aphididae** | | | |
| *Dactynotuus compositae* (Theobald) | Safflower aphid | | 24 |
| **Aleyrodidae** | | | |
| *Bemisia tabaci* (Gennadius) | Tobacco whitefly | Minor | 21 |
| **Cicadellidae** | | | |
| *Poecilocarda nigrinervis* (Stal) | Leaf hopper | Major | 24 |
| **Tenthredinidae** | | | |
| *Athalia* spp. | Cabbage sawfly | Major | 24 |
| **Lepidoptera** | | | |
| **Noctuidae** | | | |
| *Agrotis segetum* (Schiffermuller) | Southern cutworm | | 5 |
| *Heliothis armigera* (Hubern) | African bollworm | Major | 5 |

# Basic studies

## Monitoring noug fly population dynamics

In order to study the population dynamics of noug flies, yellow sticky traps were installed in noug fields at Denbi and Ghinchi during flower bud initiation, and results indicated that in 1994 at Ghinchi the fly population reached peak in September with a mean of 50 flies/trap/week, while the lowest record was in August with 10 flies/trap/week (IAR, 1994). In the 1995, the fly population reached a peak towards the end of the cropping season. By the end of October 68 and 52 flies/ trap was caught at Ghinchi and Denbi, respectively (Fig. 1). However, in the earlier periods of monitoring there was no apparent difference in the population of the flies between the two distantly located sites. These results indicate that the flies are important pests of noug demanding control mainly after flower setting (IAR, 1995).

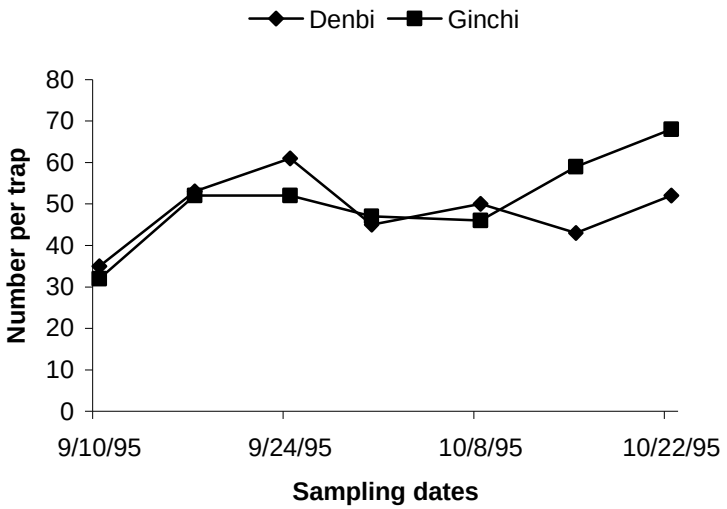


Fig. 1. Noug fly adult population dynamics at Denbi and Ghinchi in 1995.

## Population dynamics of leaf miner parasitoid

The study made on leaf miner parasitoid (*Ichneumonidae*) population dynamics from 1998 to 2000 at Adet indicated an increase in the parasitoid number as the larval population of the leaf miner increased; indicating that the efficiency of the parasitoid was dependant on prey density (IAR, 1993).

## Loss assessment study

Sesame webworm yield loss assessment at Werer Research Center using DDT 25% EC showed a yield loss of about 25.8%, and the appropriate time of sesame webworm control was at the flowering stage (IAR, 1986c). Loss assessment studies on groundnut due to striped blister beetle (*Epicauta albovittata*), African bollworm and termites (*Microterms* spp.) were conducted independently at Werer, Babile and Goffa. The studies on the African bollworm and blister beetle were made from 1991 to 1994 at Werer. Results indicated that the loss incurred on groundnut pod yield by striped blister beetle was 14.2%, while that of the African bollworm was 11.6% (Table 10).

Studies on yield loss caused by termites at Babile and Goffa indicated losses ranging from 11.2 - 82.4% at Babile, with mean field infestations of 3.1 to 11.7%. At Goffa, the crop was harvested before the yield data was taken and thus it was not possible to calculate the percentage yield loss. However, termite infestation in the field was estimated to be about 60% (Table 10) (EARO, 2004).

Table 10. Losses reported on sesame and groundnut.

| Crop | Pest | Damage (%) | Percentage of losses | | Ref. |
|---|---|---|---|---|---|
| | | | Range | Mean | |
| Sesame | Webworm | 25.8 | - | 25.80 | 15 |
| Groundnut | African bollworm | 11.6 | - | 11.57 | 23 |
| | Striped blister beetle | 14.2 | - | 14.16 | 23 |
| | Termite | 60.0 | 11.2 - 82.4 | 46.80 | 10 |

## Control measures

In order to develop integrated pest management measures for the control of pests of oil seeds in Ethiopia different research attempts were made, like cultural control, host plant resistance, botanicals and chemicals screening experiments were made and summarized as follows.

## Cultural methods

In the study conducted from 1993 to 1996 at Adet to control leaf miner damage on noug crop by manipulating sowing date, the peak foliage damage was recorded at the end of August. Sowing noug in the first week of June reduced pest attack and increased yield. The numbers of leaf miner larvae, mines, and leaf area damaged were increased as planting time delayed from mid May to late June (ARARI, 2000; 2002).

## Host plant resistance

Groundnut variety screening trials against major insect pests (African bollworm, thrips, jassid, leaf worm, and termites) were started in 1992 with 82 accessions at Werer and Babile. Every year susceptible genotypes were dropped and 10 promising genotypes were promoted to advanced variety screening (IAR, 1997; EARO, 2004). Sunflower genotypes were evaluated for their reaction to the African bollworm at Awassa and Arisi Negele. As shown in Table 11, the genotype Eliodoro gave a good degree of tolerance to the pest at both locations (IAR, 1986b).

Table 11. Mean counts of ABW on sunflower genotypes at Awassa and Arsi Negele in the 1986 cropping season (IAR, 1986b).

| Sunflower varieties | No. of ABW larvae | |
|---|---|---|
| | Awassa | Arsi Negele |
| Eliodoro | 9a | 13a |
| IS 7775 | 13ab | 18ab |
| HA-301 | 13ab | 30abcde |
| Synth-INRA-7702 | 14abc | 48cdef |
| Synth- NSH-37 | 16abc | - |
| Romsum 90 | 17abcd | 25abc |
| Synth-NSH-25 | 17abcd | 25abc |
| HA-300 | 17abcd | 30bcdef |
| NK-265 | 20abcd | 43cdef |
| Ha-302 | 20abcd | - |
| Synth-NSHD3 | 24cde | 54ef |
| Synth-NSH-2 | 24cde | 35bcde |
| Ch x gene pool I | 25de | 64f |
| Ch x gene pool II | 27de | 63f |
| Menonite | 32e | 50def |

Means followed by the same letter(s) within a column are not different at 5% level of probability (DMRT).

## Botanical control

Neem seed powder 5% by volume, noug oil at 1 ml/kg, gomenzer oil at 10 ml/kg, cotton oil at 10 ml/kg, Persian lilac seed powder 5% by volume, and pepper tree seed powder 5% by volume) were evaluated against beetles on stored groundnut seeds. Among the botanicals, crushed neem seed, gomenzer and cotton oil showed 96, 92 and 84% efficacy, respectively.

The Gas Chromatographic Meter readings showed that the oil content of beetle damaged groundnut seeds was greater than that of undamaged seeds; however, oil quality reduction was not considered in this study (Table 12).

Table 12. Effect of botanicals on red flour beetle on groundnut seeds in the 1995/96 season at Melka Werer Research Center (IAR, 1997).

| Treatments | Rate | No. of beetles introduced | No. live beetles six MAT | Efficacy (%) | Weight of healthy seeds (g) | Oil content (%) | | Germination (%) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Healthy seeds | Damaged seeds | Healthy seeds | Damaged seeds |
| Neem seed powder | 5% W/W | 50 | (1.55) de | 96.00 | 989.60 ab | 46.50 | 47.39 | 64.67 c | 20.42 |
| Noug oil | 10 ml/kg | 50 | (4.03) c | 68.00 | 964.30 bc | 46.40 | 46.83 | 77.66b | 7.94 |
| Gomenzer oil | 10 ml/kg | 50 | (1.96) de | 92.00 | 972.8 ab | 46.67 | 46.36 | 73.34bc | 8.77 |
| Cotton oil | 10 ml/kg | 50 | (2.56) d | 84.00 | 982.5 ab | 46.46 | 47.26 | 47.67d | 4.33 |
| Pepper seed powder | 5 % W/V | 50 | (11.17) a | 0.0 | 831.8 d | 46.51 | 46.83 | 91.67a | 30.00 |
| Persian lilac seed powder | 5 % W/V | 50 | (8.59) b | 0.0 | 799.7 e | 46.75 | 60.47 | 72.0bc | 14.00 |
| Pirimiphos methyl | 10 g/kg | 50 | (0.84) e | 100 | 994.4 a | 46.51 | 49.93 | 92.67a | 33.33 |
| Untreated check | - | 50 | (3.97) c | - | 939.7 c | 46.11 | 47.81 | 94.67a | 11.00 |
| Mean | - | - | 4.33 | | 934.35 | 46.49 | 49.11 | 76.79 | 16.22 |
| SE | | | 1.07 | | 2.00 | | | 11.97 | |
| CV | | | 17.16 | | 26.96 | 1.12 | 14.88 | 10.83 | |
| $LSD_{0.05}$ | | | 0.37 | | 9.36 | NS | NS | 4.16 | |

* Means in a column followed by the same letter are not significantly different at 5% level of significance (DMRT).
Data in parenthesis are square root transformed values. MAT= Month after treatment.

# Chemical control

## Sesame insect pests

Endosulfan 35% EC at 2, cypermethrin 20% EC at 4.5, Lamdacyhalothrin 5% EC at 0.32, Pirimiphos-methyl 50% EC at 2, malathion 50% EC at 2, diazinon 600 at 2 and *Bacillus thurignensis* SC at 2 l/ha, respectively were evaluated for the control of sesame webworm (*Antigastra catalalaunalis*). Out of which malathion and diazinon failed to control the webworm, while good control was obtained from endosulfan, pirimiphos-methyl, cypermethrin, thuracide and lambda-cyhalothrin treatments (Table 13). Fenithrithion, baythion, Pirimiphos-methyl, Bt, permethrin and aluminium phosphide were evaluated against storage insect pest of sesame, and it was found that fenithrithion at 30 g/t, baythion at 100 g/t, aluminium phosphide at 5 tablets, and pirimiphos-methyl at 300 ppm caused respective mortalities of 99.5, 98.7, 93.9 and 91.1% in storage beetles. Similarly, aluminium phosphide, fenithrithion and pirimiphos-methyl at the above-mentioned rates gave 94.6, 94.6 and 92.5% control of *Ephestia cautella* larvae in storage, respectively. *B. thurungeinsis* at 10g/kg of sesame seed did not control the storage beetles, and then it's efficacy on the *Ephestia cautella* larvae was only 70% (Table 14).

Table 13. Effects of insecticides on sesame webworm population and sesame yield in the 1988 season at Melka Werer Research Center (IAR, 1997).

| **Treatment** | **Mean pre-spray count** | **2 DAS** | **8 DAS** | **14 DAS** | **Yield q/ha** |
|---|---|---|---|---|---|
| Endosulfan 35% EC | 3.6 | 0 | 0.2 | 2.2 | 10.1 |
| Pirimiphos methyl 50% EC | 4.2 | 1 | 0 | 3.2 | 9.8 |
| Cypermethrin 20% EC | 1.4 | 0.4 | 0 | 0.6 | 9.9 |
| Malathion 50% EC | 3.8 | 1.6 | 0.2 | 3.2 | 9.4 |
| Diazinon 600 EC | 3.0 | 2 | 0 | 2.2 | 8.8 |
| Lambdacyhalothrin 5% EC | 2.0 | 0.4 | 0 | 1.6 | 9.7 |
| *Bacillus thurengensis* SC | 3.6 | 2 | 0.8 | 2.2 | 10.4 |
| Untreated check | 5.4 | 2.4 | 1.2 | 3.4 | 10.1 |
| Mean | 3.37 | 1.22 | 0.3 | 2.32 | 9.8 |
| SE | 1.21 | 0.66 | 0.33 | 0.89 | 0.18 |
| CV% | 72.13 | 109.05 | 205.48 | 76.86 | 16.42 |
| LSD 5% | 3.14 | 1.72 | 0.79 | 2.31 | NS |
| LSD1% | 4.24 | 2.32 | 1.07 | 3.11 | NS |

DAS = days after spraying, NS = not significant

Table 14. Effect of insecticides on the Tropical warehouse moth (*Ephestia cautella*) and red flour beetle (*Tribolium* spp.) attacking stored sesame seeds at Werer Research Center in 1995/96 (IAR, 1997).

| **Insecticide treatments** | **Rate** | **No. beetles and *Ephestia* larvae introduced** | **Mean No. beetles recovered after treatment** | **Efficacy %** | **No. *Ephestia* larvae alive after treatment** | **Efficacy %** |
|---|---|---|---|---|---|---|
| Pirimophos methyl | 300 ppm | 20 | (1.17) abc | 91.2 | (1.10) a* | 92.5 |
| Aluminium phosphide | 5 tab/100kg | 20 | (1.05) bc | 93.9 | (0.94) a | 94.6 |
| *Bacillus thuringensis* | 10 g/kg | 20 | (4.98) ab | 0 | (1.84) a | 69.6 |
| Phoxim / Baythion | 100 g /100 kg | 20 | (0.79) c | 98.7 | (1.51) a | 80.9 |
| Fenitrothion | 30 g/ 100 kg | 20 | (0.74) c | 99.5 | (0.98) a | 94.6 |
| Peremthrin | 100 g /100 kg | 20 | (1.70) abc | 76.2 | (1.47) a | 78.7 |
| Untreated check | - | 20 | (4.79) a | - | (3.42) a | - |
| Mean | - | - | 2.17 | - | 1.61 | - |
| S.E | | | 0.90 | | 0.53 | |
| CV | | | 96.19 | | 66.44 | |
| LSD 5% | | | 2.69 | | NS | |
| LSD 1% | | | NS | | NS | |

Means in a column followed by the same letter are not significantly different at 5% level of significance, DMRT.
**Data in parenthesis are square root transformed.

## Groundnut insect pest

Synthetic insecticides (malathion 50% EC at 100g/kg, aluminum-phosphide at 6 tablets/100 kg, pirimiphos-methyl 2% D at 0.5 g/kg, baythion 1% D at1 g/kg, fenithrithion 3% D at 0.25 g/kg and perimethrin 5% D at1 g/kg seed) were evaluated against weevils on stored groundnut seeds. Except aluminum-phosphide, all tested chemicals showed > 96.74% control of weevils (Table 15).

Table 15. Effects of insecticides on red flour beetle attacking stored groundnuts in 1995/96 at Werer Research Center (IAR, 1997).

| Treatments | Rate | No. weevils introduced | No. weevils alive after treatment | Efficacy (% ) | Weight of seeds | | Germination (%) |
|---|---|---|---|---|---|---|---|
| | | | | | healthy | damaged | |
| Malathion 50% EC | 100 g/ kg | 50 | (0.18) c | 99.74 | 999.35 | 0.65 a | 76 c |
| Aluminium phosphide | 6 tab/ t | 50 | (6.75) a | 21.84 | 908.7 | 91.3 bc | 87.61 ab |
| Actellic 50% EC | 50g / 0.1t | 50 | (1.35) c | 96.74 | 989.13 | 10.87 ab | 88.33 ab |
| Baythion 1D | 100g/ 0.1t | 50 | (9.78) c | 97.74 | 996.9 | 3.1 ab | 87.33 ab |
| Fenitrothion 3 D | 20-30 g/ 0.1t | 50 | (0.71) c | 100 | 998.74 | 1.26 ab | 90.00 a |
| Permethrin 5 D | 100 g/ 0.1t | 50 | (0.71) c | 100 | 999.08 | 0.92 ab | 82.00 ab |
| Untreated | - | 50 | (4.04) b | - | 940.85 | 59.15 b | 87.34 ab |
| Mean | - | - | 3.36 | - | 976.11 | 23.89 | 85.52 |
| SE | | | 0.47 | | 11.45 | | 2.79 |
| CV | | | 45.41 | | 7.33 | | 6.51 |
| LSD 5% | | | 1.39 | | 34.05 | | 8.28 |
| LSD 1% | | | 1.91 | | 46.60 | | NS |

Means within a column followed by the same letter(s) are not significantly different from each other at 5% level of significance (DMRT).
Data in parenthesis are square root transformed.

## Noug fly

In 1992, chlorpyriphos 48% EC at 1.0, cypermethrin 10% EC at 0.5, fenitrothion 50% EC at 1.5, lambda-cyhalothrin 5% EC at 0.3 and pirimiphos-methyl 50% EC at 1.0 l/ha were evaluated for their efficacy against the noug fly at Ghinchi and Debre Zeit (Tables 16, 17 and 18). In 1993, trichlorophon 50% WP at 1.0 kg/ha was included and sprayed at 50, 75 and 100% flowering stages. In 1994, profenofos 72% EC at 0.75 l/ha was added to the list of insecticides tested. Among the insecticides, lambdacyhalothrin 5% EC at the rate and number of sprays tested gave better control of the noug fly in 1992 (IAR, 1992). In 1993 and 1994, there were no statistically significant differences in the number of flies counted in all of the treatments (Tables 16 and 17). Generally,

there was a decrease in fly population through time in the pesticide treatments unlike in the untreated check where the population did not change. The seed yield was better in chlorpyriphos 48% EC treatments and the least yield was recorded in pirimiphos-methyl (Table 17). In 1994, better yield was obtained from profenofos and chlorpyriphos treatments, and the least was from Trichlorophon **(**Table 18). From the three years results it was observed that spray formulations did not penetrate into the base of the disc flowers where the fly completes its development. Spraying was scheduled to start at about 50% flowering, but if spraying was tried first at full flower budding, the result may change. In addition, nozzle arm of the sprayer used was short which might have contributed to the reduction in the efficacy of insecticides. Therefore, by scheduling the spray time earlier than used in this study and by using sprayers with longer nozzle arm the efficacy of the chemicals could be improved.

Table 16. Mean number of noug flies emerged on subsequent sampling dates and corresponding seed yields in 1992 (IAR, 1993).

| **Treatment** | **Rates (l/ha)** | **Mean number of flies in samples after insecticide spray** | | | **Yield q/ha** |
|---|---|---|---|---|---|
| | | **Fist** | **Second** | **Third** | |
| Chlorpyriphos 48% EC | 1.0 | 10 | 1 | 0 | 1.95 |
| Cypermethrin 10% EC | 0.5 | 23 | 1 | 10 | 2.14 |
| Fenitrothion 50% EC | 1.5 | 8 | 6 | 7 | 1.59 |
| Lamdacyhalothrin 5% EC | 0.3 | 15 | 1 | 2 | 2.69 |
| Pirimiphos-methyl 50% EC | 1 | 3 | 0 | 4 | 1.60 |
| Unsprayed check | - | 20 | 35 | 26 | 1.20 |

Table 17. Effects of insecticides on noug fly population and the corresponding seed yields in 1993 (IAR, 1994).

| **Treatment** | **Rate (l/ha)** | **Log transformed fly count after sprays** | | | **Yield (q/ha)** |
|---|---|---|---|---|---|
| | | **First sample** | **Second** | **Third** | |
| Chlorpyriphos 48% EC | 1.0 | 0.97 | 0.93 | 0.58 | 2.11 |
| Cypermethrin 10% EC | 0.5 | 0.99 | 0.52 | 0.89 | 1.60 |
| Fenitrothion 50% EC | 1.5 | 0.66 | 0.87 | 0.72 | 1.59 |
| Lamdacyhalothrin 5% EC | 0.3 | 1.05 | 0.8 | 0.69 | 1.45 |
| Pirimiphos-methyl 50% EC | 1.0 | 0.87 | 0.75 | 0.56 | 1.00 |
| Trichlorophon 50% WP | 1.0 | 0.86 | 0.74 | 0.75 | 1.34 |
| Unsprayed check | - | 0.61 | 0.84 | 071 | 1.17 |
| LSD 5% | | NS | NS | NS | 0.84 |
| CV | | 24.3 | 47.3 | 53.4 | 33.1 |

Table 18. Mean number of noug flies emerged on subsequent sampling dates and corresponding yields in 1994 (IAR, 1995).

| Treatment | Rates (l/ha) | Mean number of flies after sampling | | | | Yield q/ha |
|---|---|---|---|---|---|---|
| | | First sample | Second sample | Third sample | | |
| Chlorpyriphos 48% EC | 1.0 | 1.11 | 1.12 | 0.83 | 0.77 | 4.25 |
| Cypermethrin 10% EC | 0.5 | 0.81 | 0.91 | 0.67 | 0.80 | 3.74 |
| Fenitrothion 50% EC | 1.5 | 0.78 | 1.11 | 0.70 | 0.94 | 3.6 |
| Lamdacyhalothrin 5% EC | 0.3 | 0.73 | 1.11 | 0.73 | 0.77 | 3.21 |
| Pirimiphos methyl 50% EC | 1.0 | 0.46 | 1.07 | 0.92 | 0.66 | 3.75 |
| Trichlorophon 50% WP | 1.0 | 0.91 | 0.98 | 0.86 | 0.66 | 2.47 |
| Profenophos 72% EC | 0.75 | 0.91 | 1.07 | 1.05 | 0.85 | 4.89 |
| Unsprayed check | - | 0.96 | 1.20 | 1.02 | 0.56 | 3.78 |
| LSD 5% | - | NS | NS | NS | NS | NS |
| CV | - | 35.1 | 22.6 | 30.1 | 30.3 | 42.7 |

### Noug leaf miner

Chemical screening in 1993 and 1994 at Adet using cypermethrin, fenitrothion, pirimiphos methyl, and endosulfan showed significant differences in damage between the insecticide treatments and the untreated check. However, the study lacked consistency in the following years due to variations in the level of leaf miner infestation (ARARI, 2000; 2002).

## Conclusion and recommendations

Sesame seed bug and webworm are serious pests on sesame, while blister beetles, jassids, the African bollworm and thrips are important on groundnut. Among the storage pests, the Tropical ware house moth (*Ephestia cautella*) and red flour beetle (*Tribolium* spp.) caused significant damage to seeds of both crops. Termites are serious problems on almost all crops in most of the drier areas. Noug fly, leaf miner and the black pollen beetle are major pests of noug, while black thrips and the African bollworm are of minor importance.

- Groundnut genotypes such as ICGV 88429, ICGV 88308, and ICGV 88338 were found to be relatively tolerant to leaf eaters and sucking insect pests. Thus, these genotypes should be verified and included in breeding programs
- Noug leaf miner damage could be minimized by sowing the crop from the first to second week of June

- Applications of endosulfan 35% EC at 2 l /ha, cypermethrin 20% EC at 4.5 l /ha, Lambdacyhalothrin 5% EC at 0.32 l /ha, pirimiphos-methyl 50% EC at 2 l /ha and *Bacillus thurignensis* SC at 2 l /ha at the economic threshold level of 30% larval infestation effectively controlled sesame webworm
- Storage beetles and webworm on groundnut could effectively be controlled by malathion 50% EC at 100 g/kg, pirimiphos-methyl 2% D at 0.5 g /kg, phoxin 1% D at 1g/kg, fenitrothion 3% D at 0.25g /kg and peremethrin 5% D at 1 g /kg of seeds
- Neem seed powder at 5% w/v, gomenzer oil at 10 ml /kg and cotton seed oil at 10 ml/kg were equally effective as synthetic insecticides. Therefore, it is possible to protect seeds intended for planting purpose with either of the two options. If the seed is for consumption purpose, it is better to keep it unshelled or treat it with one of the botanicals
- Fenitrothion at 30 g/100 kg of seeds and aluminium phosphide at 6 tab/100 kg of seeds could be used as effective insecticides for the control of both webworm and beetles in sesame. Webworm could also be controlled by Baythion at 100 g/100 kg of seed
- Lambda cyhalothrin 5 % EC at 0.3 l /ha and chlorpyripos 48% EC at 1 l /ha could be recommended for noug fly management

## Gaps and challenges

- Currently, sesame seed bug is a number one pest that poses considerable quantitative and qualitative losses on sesame in the northwestern part of the country. Lack of knowledge on its biology in particular hindered the possible intervention in the development of management tactics. The means of survival during dry season and the type and relationship with the alternative hosts must be studied
- As sesame seed is an export commodity, the use of synthetic insecticides on the crop pose great danger due to stringent quality control measures of importing countries. Therefore, there is an urgent need for the development of safe and acceptable control methods that reduce or exclude the use of synthetic chemicals
- Despite the importance of termites in all of the sesame and groundnut growing regions, the efforts made in the past to control termites were minimal
- Thrips, whitefly, aphids, and jassids play important role in transmitting viral, mycoplasma and bacterial diseases of sesame and groundnut. Phyllody disease of sesame, which is transmitted by jassids, is the expanding problem of the crop in drier areas of the country
- Research on insect pests on safflower did not get any attention at all.

### Noug, brassica and linseed pests

- The yield losses incurred by the major insect pests of noug are not complete
- Effective chemicals have not been identified, despite all the efforts made so far to screen insecticides
- The relative importance of the major insect pests identified to date has not been established at a national level
- Alternative control measures have never been studied except for the noug leaf miner which could be controlled by adjusting sowing dates
- Insect problems on brassica, safflower, sunflower and linseed received very little attention

## Future

- Research on the integrated control of termites should be the area of future research focus
- Potential cultural control methods (sowing dates, mulching, manuring, land preparation, crop rotation, etc.) should be evaluated for the management of different pests of oil crops
- Special attention should be given to research on botanicals, seed dressing insecticides and bio-pesticides
- The biology of sesame seed bug and its management through non-chemical methods such as cultural practices, botanicals and biological agents must be studied
- Loss assessment study on sesame phyllody disease and management of the insect vector should be studied
- Groundnut insects that directly damage the crop by feeding and at the same time serve as vectors of diseases should be studied and strategies must be developed for their management
- The biology, population dynamics, loss assessment, economic threshold and management studies on noug fly, leaf miner, thrips and pollen beetle attacking noug should be studied

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# Review of Research on Coffee, Tea and Spices Insect Pests in Ethiopia

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## Introduction

Ethiopia is the origin of coffee, *Coffea arabica* L., and coffee is one of the most valuable crops in the country. It accounts for 55% of the total export earnings, 10% of the government revenue and employs 25% of the domestic labor force (Tsegaye *et al*., 2000). Coffee is grown in different production systems, namely forest, semi forest, garden, and intensive coffee production systems (Workafes and Kassu, 2000). Ethiopia is also homeland for many spices such as Korarima, *Aframomum korarima*, Long pepper, *Piper* spp., Coriander, *Coriandrum sativum*, Black cumin, *Nigela sativum* (Jonson 1981). In the southwestern and southern parts of Ethiopia, some exotic spices are also grown due to the existence of favorable climatic conditions (Edossa, 1998). Currently, there is an increasing domestic and commercial interest for spices production in Ethiopia.

Although Ethiopia is the homeland for Arabica coffee and the environmental conditions are suitable for coffee production, the average national yield is very low. Insect pests are among the factors considered to limit coffee production in both quality and quantity (Million and Bayissa, 1986; Million, 1987; 2000). Over 47 species of insect pests are recorded on coffee in Ethiopia (Crowe and Tadesse, 1984; Million and Bayissa, 1986; 1987), among which the antestia bugs (*Antestiopsis intricate* and *A. facetoides*) and coffee blotch miner (*Leucoptera caffeina*) are the major ones inflicting considerable damage. Moreover, insect pests such as coffee berry borer, (*Hypothenemus hampei*), coffee thrips (*Diarthrothrips coffeae),* green scale (*Coccus alpinus*) and coffee cushion scale (*Stictococcus formicarius*) are potentially important pests which need research attention. Insect pest problems are more pronounced in intensive coffee production system compared to garden coffee and semi-forest production systems mainly due to changes in cultural practices associated with the newly planted cultivars (Million, 1987).

In Ethiopia, most of the insect pests of coffee are of minor importance as opposed to many coffee producing countries. One of the possible reasons is the existence of diverse natural enemy communities, which keep the population at a low level mainly in the relatively undisturbed coffee ecosystems, where pest and natural enemy balance is maintained (Crowe and Tadesse, 1984; Million and Bayissa, 1986; Million 2000). In addition, the genetic diversity of Arabica coffee coupled with cultural practices with minimum or no input used by subsistence farmers (Tsegaye *et al*., 2000) could have contributed to the suppression of insect pests of coffee. Nevertheless, if there are any adverse agronomic/ farm practices that affect the natural biological balance between pest and their natural enemies, these minor pests can pose a serious problem to coffee industry. Extensive surveys and identification of coffee insect pests and their natural enemies (Schmutterer, 1971; Crowe *et al*., 1977; Crowe and Tadesse, 1984; Million and Bayissa, 1986; Million, 1987) and some basic studies and pest management methods such as the role of insect natural enemies were conducted.

Despite the increasing importance of tea and spices very limited studies have been conducted on pests of these crops. Lists of insect and mite pests of tea and spices were compiled by (Tsedeke, 1988). This review summarizes coffee, tea and spices insect pests research undertaken in the past two decades in Ethiopia.

# Research findings

## Pests recorded

### Insect pests of coffee

Insect and mite pests of coffee recorded in Ethiopia are listed in Table 1. To date about 47 species of arthropod pests have been recorded on coffee in Ethiopia (Crowe *et al*., 1977; Crowe and Tadesse, 1984; Million and Bayissa 1986; Million, 1987). Most insect pests of coffee found in Ethiopia, however, are of minor economic importance in contrast to many other coffee growing countries.

### Insect pests of Tea (*Camellia sinensis*)

List of insect pests of tea has been compiled by Tsedeke (1988). All the reported pests have minor importance except the coffee aphid (*Toxoptera aurantii)* which is a major pest of young leaves of tea seedlings (Table 2). Very recently, high infestation of aphid was observed on tea seedlings in a nursery at the Jimma Agricultural Research Center (Esayas Mendesil, 2006, unpublished).

Table 1. Insect and mite pests of coffee recorded in Ethiopia.

| Scientific name | Common name | Status | References |
|---|---|---|---|
| **Coleoptera** | | | |
| **Cerambycidae** | | | |
| *Anthores leuconotus* Pascoe | White coffee borer | Minor | 2, 18 |
| **Curculionidae** | | | |
| *Systates* sp. | Systates weevil | Minor | 1 |
| **Tenebrionidae** | | | |
| *Gonocephalum simplex* (Fabricius) | Dusty brown beetle | Minor | 2, 18 |
| Family? | | | |
| *Sophronica* sp. | | Minor | 45 |
| **Bostrichidae** | | | |
| *Apate indistinctus* Murray | Black borer | Minor | 1, 2 |
| *A. monachus* Fabricius | Black borer | Minor | 2 |
| **Scolytidae** | | | |
| *Hypothenemus hampei* (Ferriere) | Coffee berry borer | Minor | 2,3,18,23 |
| **Lepidoptera** | | | |
| **Notodontidae** | | | |
| *Anaphe panda* (Boisduval) | African silk worm | Minor | 2 |
| **Geometridae** | | | |
| *Ascotis selenaria reciprocaria* Walker | Giant lopper | Minor | 40 |
| **Gracillaridae** | | | |
| *Cryphiomystis aletreuta* (Meyrick) | Serpentine leaf miner | Minor | 16, 17, 18 |
| **Tortricidae** | | | |
| *Archips occidentalis* (Wals.) | Green tortrix | Minor | 14, 31, 34 |
| *Cryptophlebia batrachopa* (Meyrick) | Berry worm | Minor | 22, 24, 25 |
| *Tortrix dinota* Meyrick | Brown tortrix | Minor | 40 |
| **Lycenidae** | | | |
| *Deudorix lorisona* Hewitson | Coffee berry butterfly | Minor | 22 |
| **Sphingidae** | | | |
| *Cephonodes hylas* (Linnaeus) | Coffee hawk moth | Minor | 2 |
| **Cossidae** | | | |
| *Eulophonotus myrmeleon* (Felder) | Cocoa stem borer | Minor | 2, 17 |
| *Duomitus* sp. | Cossid stem borer | Minor | 2,17, 25 |
| **Ethmiidae** | | | |
| *Ethmia iphicartes* (Meyrick) | Branch borer | Minor | 23 |
| **Epiplemidae** | | | |
| *Leucoplema dohertyi* (Warren) | Coffee leaf skeletonizer | Minor | 2, 16,17,18 |
| **Lyonetiidae** | | | |
| *Leucoptera caffeina* Washbourn | Coffee blotch miner | Major | 1, 22, 23 |
| *L. meyricki* Ghesquiere | Coffee blotch miner | Minor | 1, 2, 16 |
| **Olethreutidae** | | | |
| *Olethreutes* sp. | Berry boring moth | Minor | 2, 13, 20 |
| **Cochlidiidae** | | | |
| *Parasa vivida* (Walker) | Stinging caterpillar | Minor | 2, 18, 19 |
| **Pyralidae** | | | |
| *Prophantis smaragdina* (Butler) | Coffee berry moth | Minor | 2, 20, 22 |

Table 1. Contd.

| **Scientific name** | Common name | Status | References |
|---|---|---|---|
| **Hemiptera** | | | |
| **Pentatomidae** | | | |
| *Antestiopsis facetoides* (Greathead) | Antestia bug | Major | 13, 20 |
| *A. intricata* (Ghesquiere and Carayon) | Antestia bug | Major | 13, 20 |
| *A. orbitalis qhesquieri* Carayon | Antestia bug | Minor | 13, 20 |
| **Heteroptera** | | | |
| **Miridae** | | | |
| *Lamprocapsidea coffeae* (China) | Coffee capsid | Minor | 1,2,17 |
| *Lygus coffeae* China | Coffee lygus | Minor | 13 |
| **Homoptera** | | | |
| **Aphididae** | | | |
| *Toxoptera aurantii* (Boyer de Fanscol.) | Coffee aphid | Minor | 13 |
| **Coccidae** | | | |
| *Avricus arborescens* (Laing) | Coffee bark scale | Minor | 2 |
| *Ceroplastes brevicauda* Hall | White waxy scale | Potential | 13, 15 |
| *Coccus alpinus* De Lotto | Green scale | Potential | 1, 13, 25 |
| *Saissetia coffeae* (Walker) | Halmet scale | Minor | 2, 15, 24 |
| **Diaspididae** | | | |
| *Ischnaspis longirostris* (Signoret) | Black thread scale | Minor | 50 |
| *Lepidosaphes beckii* (Newman) | Citrus mussel scale | Minor | 13 |
| *Selenaspidus articulatus* (Morgen) | Rufous scale | Minor | 2, 15, 24 |
| **Stictococcidae** | | | |
| *Stictococcus formicarius* (Newstead) | Coffee cushion scale | Potential | 2, 13, 15 |
| **Diptera** | | | |
| **Tephritidae** | | | |
| *Ceratitis capitata* (Wiedemann) | Mediterranean fruit fly | Minor | 2, 15, 18 |
| *C. rosa* Karsch | Natal fruit fly | Minor | 2, 13 |
| *Trirhithrum coffeae* (Bezzi) | Coffee fruit fly | Minor | 2, 13, 18 |
| **Agromyzidae** | | | |
| *Tropicomyia flacourtiae* | Coffee leaf fly | Minor | 2 |
| **Thysanoptera** | | | |
| **Thripidae** | | | |
| *Diarthrothrips coffeae* Williams | Coffee thrips | Potential | 2, 15, 17 |
| *Selenothrips rubrocinctus* (Giard) | Coffee thrips | Minor | 2 |
| **Acarina** | | | |
| **Eriophyidae** | | | |
| *Diptilomiopus* sp. | Coffee bronze mite | Minor | 2, 15, 17 |
| *Oligonychus coffeae* (Nietner) | Red coffee mite | Minor | 1 ,2 |
| **Tenuipapidae** | | | |
| *Brevipalpus* sp. | Red crevice mite | Minor | 2, 17 |

Table 2. Insect pests recorded on tea in Ethiopia (after Tsedeke, 1988).

| Scientific name | Common name | Status |
|---|---|---|
| **Coleopetra** | | |
| **Apionidae** | | |
| *Apion* spp. | Black pod weevil | Unknown |
| **Lagridae** | | |
| *Lagria villosa* Fabricius | Metallic leaf beetle | Minor |
| **Homoptera** | | |
| **Aphididae** | | |
| *Toxoptera aurantii* (Boyer de Fonsc.) | Coffee aphid | Major |
| **Coccidae** | | |
| *Coccus viridis* (Green) | Green scale | Minor |
| *Coccus hesperidum* (L.) | Soft brown scale | Unknown |
| *Parasaissetia nigra* (Nietner) | Black helmet scale | Minor |
| *Saissetia coffeae* (Walker) | Helmet scale | Minor |
| **Diaspidae** | | |
| *Chrysomphalus dictyospermi* (Morgan) | Orange scale | Unknown |
| **Orthoptera** | | |
| **Acrididae** | | |
| *Catantops melanostictus* Schaum | Tea grasshopper | Minor |

### Insect pests of spices and herbs

Insect pests recorded on basil (*Ocimum* spp.), chicory (*Cichorium intybus)*, dill (*Anethum graveolens)*, fennel (*Foeniculum vulgare)*, parsley (*Petroselinum crispum)*, rhubarb (*Rheum rhaponticum)* and rue (*Ruta graveolens)* in Ethiopia are listed in Table 3.

## Basic studies

### Antestia bug, *Antestiopsis* spp.

There are three species of *Antestiopsis* in Ethiopia, namely *Antestiopsis intricata*, *A. facetoides* and *A. oribitalis*. *Antestiopsis intricata* is the most common bug found in all coffee growing areas except Hararghe, eastern Ethiopia where only *A. facetoides* was found (Crowe and Tadesse, 1984; Million, 1987). *A. orbitalis* was collected from a small coffee plot in Sebeta, near Addis Ababa as part of the FAO coffee mission in Ethiopia in 1964 (Greathead, 1968), but its presence has yet to be confirmed (Million, 2000).

### Biology

The biology of *A. intricata* is shown in Table 4. Eggs are mostly laid on the underside of leaves usually in batch of 12. The egg stage ranges from 3 to 5 days, the average being 3.6 days (Million, 1987). Esayas and Million (2004) recorded 6-8 days. The average durations of the five nymphal instars were 5.5,

8.6, 8.5, 10.0 and 18.4 days, respectively (Million, 1987). In another study, a respective mean developmental periods of 6.6, 10.3, 7.5, 8.9 and 9.7 days were reported for the instars (Esayas and Million, 2004). The average longevity, for the female and male bugs was 187 ± 7.8 and 135 ± 10 days, respectively (Esayas and Million, 2004), whereas Million (1987) reported the average longevity to be 95 days. Such variation in the developmental period may be attributed to differences in temperature and relative humidity conditions of the experimental environment. The average oviposition period of the insect was found to be 134.8± 12 days. Each female insect laid 12 eggs/ day on the average and total of 324 ± 10 eggs/ female (Table 5). Highly significant and negative correlation ($r = -0.91$, $P < 0.01$) was found between the number of eggs laid per female and days after adult female emergence (Esayas and Million, 2004).

Table 3. Insects pests of spices and herbs recorded in Ethiopia (modified from Tsedeke, 1988).

| Scientific name | Common name | Crop infested | Status |
|---|---|---|---|
| **Coleoptera** | | | |
| **Chrysomelidae** | | | |
| *Aspidomorpha quadrimaculata* Oliv. | Sweet potato tortoise beetle | Basil | Unknown |
| *Decaria abdominalis* Jacoby | Noug flea beetle | Rhubarb | Unknown |
| *Eugasteroides loricatus* (Gestacker) | Spiny bush cricket | Rhubarb | Unknown |
| **Lepidoptera** | | | |
| **Noctuidae** | | | |
| *Agrotis segetum* (Schiff.) | Cutworm | Chicory | Unknown |
| **Homoptera** | | | |
| **Aphididae** | | | |
| *Dactynotus cichorii* (Koch.) | Chicory aphid | Chicory | Unknown |
| **Homoptera** | | | |
| **Aphididae** | | | |
| *Cavariella aegopodii* (Scopoli) | Carrot aphid | Dill, fennel, parsley | Uncertain* |
| *Dysaphis foeniculus* (Theobald) | Fenel aphid | Dill | Unknown |
| **Margarodidae** | | | |
| *Icerya purchasi* | Cottony cushion scale | Fennel, rue | Unknown |
| **Diaspidae** | | | |
| *Aonidiella orientalis* (Newstead) | Oriental scale | Rue | Unknown |
| **Heteroptera** | | | |
| **Pentatomidae** | | | |
| *Doryocoris pavoninus* (Wesw.) | Rhubarb bug | Rhubarb | Unknown |
| **Coleopteran** | | | |
| **Chrysomelidae** | | | |
| *Hatica pyritosa* Erichson | Linseed flea beetle | Rhubarb | Unknown |

* Heavy damage on fennel was observed and occasional pest of parsley.

Table 4. The biology of antestia (Esayas and Million, 2004).

| Stage | Range (Days) | Mean |
|---|---|---|
| Egg | 6-8 | 7.4 ± 0.2 |
| Nymphal instars | | |
| First instar | 6-8 | 6.6 ± 0.2 |
| Second instar | 9-13 | 10.3 ± 0.5 |
| Third instar | 7-10 | 7.5 ± 0.7 |
| Fourth instar | 6-14 | 8.8 ± 1.2 |
| Fifth instar | 7-14 | 9.7 ± 1.0 |
| Adult longevity | | |
| Female | 127-272 | 187.0 ± 7.8 |
| Male | 53-241 | 135.2 ± 10 |
| Total life cycle | | |
| Female | 168-339 | 237.3 ± 7.8 |
| Male | 94-308 | 185.5 ± 10 |

Table 5. Oviposition and fecundity of antestia bug (after Esayas and Million, 2004)

| Events | Range | Mean |
|---|---|---|
| Pre oviposition period | 2 - 11 | 4.7 ± 0.9 |
| Oviposition period | 74 - 227 | 134.8 ± 12 |
| No. of eggs laid per female per day | 7 - 12 | 12 ± 0.4 |
| Total no. of eggs per female | 61 - 457 | 324 ± 10 |
| No. of eggs per batch | 7 - 12 | 12 ± 0.4 |
| Total no. of egg bathes per female | 9 - 42 | 30.5 ± 2.7 |
| No. of days between successive oviposition | 0 - 30 | 5.0 ± 0.4 |
| Percent egg viability | 42 - 100 | 87.3 ± 0.7 |
| Sex ratio (female to male) | 1:1 - 1:2 | 1:1 ± 0.1 |
| Post oviposition period | 9 - 67 | 31.1± 4.5 |

± = standard error

## Population dynamics

Weekly counts of antestia bugs at Tepi and Metu Research sub-Centers from 1989-1993 indicated that, the population density of the insect increased at Metu relative to the previous record (Table 6). However, at Tepi the population density was found to be reduced. Generally, results of antestia counts at different coffee growing localities indicated that the population builds up starting around March and reach its peak in May/June (Million, 1987). The spatial dispersion behavior of the insect showed that the pest has a highly significant occurrence in an aggregated manner with non-significant effects on

location. Taylor's power law was a better describer of dispersion of the insect and the level of recorded aggregation can be considered to determine the number of coffee trees and the frequency of sample size to monitor antestia bug (IAR, 1996b; 1997b).

Table 6. Mean antestia bug population at Metu and Tepi (after IAR, 1996a and 199b).

| Months | Mean antestia bug/tree | | | | | | |
|---|---|---|---|---|---|---|---|
| | Metu | | | | | Tepi | |
| | 1976/82 | 1989-90 | 1991 | 1992 | 1993 | 1976/82 | 1989-90 |
| January | 1.3 | - | 24.6 | 8.0 | 2.9 | 6.22 | - |
| February | 1.7 | - | 27.4 | 3.6 | 1.6 | 6.27 | - |
| March | 1.1 | - | 13.8 | 5.1 | 3.0 | 3.23 | - |
| April | 1.5 | 11.4 | 11.4 | 4.5 | 4.7 | 9.32 | 5.7 |
| May | 1.6 | 7.6 | 1.0 | 5.2 | 6.3 | 8.00 | 6.7 |
| June | 1.4 | 7.4 | 8.5 | 3.7 | 6.8 | 5.93 | 8.7 |
| July | 1.6 | 1.0 | 1.0 | 2.2 | 4.1 | 6.02 | 4.8 |
| August | 1.5 | 6.0 | 7.2 | 1.4 | 4.1 | 5.62 | 8.3 |
| September | 1.2 | 8.3 | 6.5 | 1.8 | 4.0 | 5.35 | 0.3 |
| October | 1.1 | 8.1 | 12.0 | 0.2 | 2.3 | 4.79 | - |
| November | 0.5 | 10.5 | 4.2 | 0.8 | 1.2 | 5.04 | - |
| December | 0.6 | 12.1 | 2.3 | 1.7 | 2.3 | 5.11 | - |
| Mean | 1.3 | 9.04 | 11.2 | 3.2 | 3.6 | 6.33 | 5.0 |

## Host range of antestia bug

The most favorable host of this insect is the Arabica coffee followed by *C. canephora* Pierre (Le Pelley, 1968; Million, 1987). It was once recorded on orange flowers in Aleta Wondo area, in southern Ethiopia (Tadesse and Bayissa, 1981). It has been also observed on Mauritius thorn at the time when large green coffee berries are absent (Crowe and Tadesse, 1984).

## Loss assessment

Antestia bugs suck green berries, flower buds, and growing tips resulting in blackening of flowers and flower buds. It also causes fall of immature berries and shortening of internodes (Crowe and Tadesse, 1984; Million, 1987). In Ethiopia, antestia bugs can cause about 9% berry fall (Mekuria *et al*., 1993), and up to 48% berry darkening (Million, 1988; IAR, 1996a; 1996b). Mekasha (1993) reported that branches of coffee trees infested with four pairs of the bug caused the highest number of damaged coffee flower buds (1.2), 54.1% of berry fall, 90.2% of bean damage, and the lowest yield (0.41 kg/tree) of red cherry (Table 7).

Table 7. Effect of antestia on flower buds, berry loss, berry fall, bean damage and yield (after Mekasha, 1993).

| No. antetia/tree | No. damaged flower buds/ branch | Berry loss/ branch (%) | No. berry fall/tree | Damaged fallen berries (%) | Bean damaged/100 red cherries (%) | Red cherry yield /tree (kg) |
|---|---|---|---|---|---|---|
| One sexed pair | 0.253 bc | 45.693 | 13.94 b | 49.11 a | 28.56 bc | 0.969 ab |
| Two sexed pairs | 0.420 bc | 42.303 | 15.72 b | 60.18 a | 20.57 bc | 1.528 a |
| Three sexed pairs | 0.547 b | 66.413 | 51.94 a | 58.72 a | 45.05 b | 0.507 b |
| Four sexed pairs | 1.223 a | 69.280 | 54.06 a | 71.66 a | 90.18 a | 0.408 b |
| Control | 0.060 c | 32.277 | 4.49 c | 21.11 b | 6.48 c | 1.617 a |
| CV (%) | 47.82 | 38.83 | 14.24 | 24.80 | 53.11 | 44.79 |

# Control measures

## Cultural methods

Cultural practices such as pruning of coffee trees and shade tree regulation can reduce the antestia populations by producing unfavorable conditions, since they prefer dense coffee foliage (Crowe and Tadesse, 1984; IAR, 1996c). A significant reduction of coffee berry loss and bean damage was obtained through pruning. Pruning also increased the efficacy of insecticides applied for the control of the bugs. However, it did not influence flower bud damage, coffee bean development, and yield (Mekasha, 1993).

## Host plant resistance

Five selections of coffee with compact, semi-compact, and open canopies were evaluated for antestia damage and results showed that antestia infestations are not related to the density canopy (Mekasha, 1993). A laboratory feeding preference test using coffee berry disease (CBD) resistant selections revealed variations in antestia feeding preference (surface and actual darkened bean injuries) among the selections (IAR, 1997a). In addition, antestia bugs fed on different CBD resistant selections showed no significant differences in the nymphal periods, but differences in the duration of adult stages was significant (IAR, 1996a).

## Botanical control

Crude extracts of *Milletia ferruginea* (Hochest) Baker and *C. cinerariaefolium* L. induced adult mortalities of 83.9 and 78.7%, respectively, 12 and 24 hrs after treatment. These botanicals also caused significantly ($P < 0.05$) the highest

mortality of nymphs, 77.7 and 79.4 after 12 and 24 h of treatment with *Milletia ferruginea* and *C. cinerariaefolium*, respectively (Table 8). In addition, *M. ferruginea*, *Chenopodium ambrosioides* and *Ekberga sp*. and *Myrsine africana* significantly inhibited hatching of the eggs, indicating the ovicidal activity of the botanicals (Esayas and Chemeda, 2007a).

Table 8. Effect of crude extracts of five botanicals on adult and nymph mortality of antestia bug (after Esayas and Chemeda, 2007a).

| Treatment | Mortality of adults and nymphs (%) | | | | | |
|---|---|---|---|---|---|---|
| | 12 h | | 24 h | | Cumulative mortality | |
| | adults | nymphs | adults | Nymphs | | |
| *Milletia ferruginea* | 83.85 | (60.00 | 0.00 | 17.71 | 83.85 a | 77.71 a |
| *Chenopodium ambrosioides* | 48.93 | (27.29 | 15.00 | 28.77 | 63.93 abc | 56.06 b |
| *Chrysanthemum cinerariaefolium* | 55.37 | 52.86 | 23.36 | 26.56 | 78.73 ab | 79.42 a |
| *Myrsine africana* | 30.00 | 8.85) | 36.85 | 6.15) | 66.85 abc | 15.00 c |
| *Ekberga* sp. | 48.93 | 37.72) | 8.85 | 6.15) | 57.78 bc | 43.37 b |
| Control (Water) | 0.00 | (0.00 | 6.15 | 6.15) | 6.15 c | 6.15 c |
| CV (%) | | | | | 20.07 | 22. 62 |

## Biological methods

Antestia eggs (45–50%) are attacked by three species of parasitoids, predominantly by *Asolcus suranus* Nixon followed by *Hadronotus antestiae* Dodd (Hymenoptera: Scelionidae) and *Anastatus antestiae* Ferriere (Hymenoptera: Eupelmidae) accounted for 33, 7 and 3% of egg parasitization, respectively (IAR, 1985; 1986a; 1986b; 1987; Million, 1987). At all of the survey areas except Mugi, *A. Suranus* was the most abundant followed by *A. antestiae* and *H. antestiae* (Table 9) (Million, 1999a). At Mugi. *A. antestiae* was more abundant than the other two species. Million (1986) described characteristics such as egg caps openings, and color and shape of excreta used in identifying the parasitoids (Table 10). In addition, a secondary parasite, *Pediobuis* sp., was recorded from Metu (IAR, 1986b; 1987; Million, 1999a). Only 5% of adults were attacked by two species of parasitoids, namely, *Corioxenos antestiae* Blair and *Bogosia rubens* (Villeneave) (Million, 1987). Crowe and Tadesse, (1984) recommended simple biological control methods of the antestia bug. Egg masses of the insect can be collected by hand and hung in a basket away from the coffee plants. Parasitoids coming out of the eggs can fly in to the coffee, while the antestia nymphs remain behind to die. Mantids were also found to be the most important predators of antestia nymphs and adults in most coffee growing areas (IAR, 1984). It was noted that some parasitoids that

exist in Kenya do not exist in Ethiopia and vice versa. Hence, there is a possibility to introduce parasitoids for classical biological control of the insect.

Table 9. Population of antestia egg parasitoids (after Million, 1999a).

| Species | Percentage abundance by location | | | |
|---|---|---|---|---|
| | Jimma | Mugi | Metu | Mean |
| *Asolcus suranus* | 80.5 | 40.0 | 79.5 | 66.7 |
| *Anastatus antestiae* | 11.0 | 54.0 | 11.0 | 25.3 |
| *Hadronotus antestiae* | 8.5 | 1.5 | 0.0 | 3.3 |
| *Pediobius spp.* | 0.0 | 4.5 | 9.5 | 4.7 |

Table 10. Characteristics used in identifying two egg parasites of antestia (after Million, 1986).

| Parasite species | |
|---|---|
| ***Asolcus suranus*** | ***Anastatus antestia*** |
| **Exit hole relatively large** | **Exit hole relatively smaller** |
| Exit hole with some remains of the egg cap of the host, found suspended over the exit hole or into the egg cavity | No remains of egg cap, clean exit hole |
| Exit hole usually remains within the egg cap of the host egg | Exit hole may extend out of the egg cap of host egg |
| Excreta is light yellow, semicircular in shape having a uniform structure | Excreta is light brown, various shape and number of small pellets attached together making up the excreta |

## Chemical methods

List of chemical insecticides that can control antestia bug are shown in Table 11. Insecticides such as Chlorpyrifos 48% EC (Dursban 4), Cypermetrin (Nurelle D 25/360 EC), Fenitrothion (Sumithion 50% EC) were reported to control antestia bug effectively (Mekasha, 1993). Earlier, Crowe and Tadesse (1984) recommended Trichlorfon 95% SP at 500g/ha. Spraying should be done when the average population of antestia (adult plus nymphs) reached more than 5 per coffee tree (Crowe and Tadesse, 1984). However, in order to conserve indigenous natural enemies, the use of chemical insecticides should be reduced and priority should be given to biological control and other alternative control methods.

Table 11. Chemical insecticides recommended for the control of antestia bug on coffee in Ethiopia.

| Insecticides | Rate (l /ha) | Reference |
|---|---|---|
| Chlorpyrifos 48% EC (Dursban 4) | 1.5 | 32, 39 |
| Cypermetrin (Nurelle D 25/360 EC) | 1.125 | 39 |
| Cypermetrin (Fenom 100 EC) | 0.8 | 39 |
| Fenitrothion (Sumithion 50% EC) | 1.8 | 1, 30, 39 |
| Lamadacyhalotrin 5.0 EC (Karate) | 0.4 | 39 |
| Malathion 50% EC | 2.5 | 1 |
| Trichlorfon 95% SP | 500g/ha | 1 |

## Coffee blotch miners (*Leucoptera* spp.)

Coffee blotch miner is one of the major insect pests of coffee in Ethiopia. There are two species of blotch miners attacking coffee leaves, namely *Leucoptera meyricki* (Ghesquiere) and *L. caffeina* Washbourn (Crowe and Tadesse, 1984; Million, 1987). The latter is the most important, commonly occurring in shaded coffee. The other species is of minor importance in Ethiopia probably because coffee is grown under shade (Million, 1987). It is the most damaging species in other coffee growing countries such as Kenya, Tanzania, Uganda, and Zimbabwe (Nyambo *et al*., 1998).

### Biology

Eggs are laid on the upper surface of the leaf by a small white moth, either in a straight line (*L. caffeina)* or in a group of 5–8 (*L. meyricki).* The larva feeds inside a leaf just below the upper epidermis resulting in leaf damage (Crowe and Tadesse, 1984). Brownish blotch, covering an area ranging from a small spot up to three quarter of a leaf, is created depending upon the number of larvae and the size of leaf attacked (Million 2000). The larval period ranges from about 20–34 days. Pupation takes place either on the tree or on fallen leaf. The pupal period varies from 7–14 days. The adult is a tiny white moth about 2 mm long and the female moth lives about two weeks (Crowe and Tadesse, 1984).

### Loss assessment

High infestation of blotch leaf miner has been observed in various coffee growing areas such as Agaro, Mugi, Haru, and Sidama and in coffee plantations viz. Tepi, Bebeka, and Goma II. Although no yield loss data is available, severe defoliation because of high infestation is expected to decrease yield considerably (Million 2000). Studies conducted at Agaro sub-Center indicated that the magnitude of leaf damage due to this insect ranged from 2.2-55% with an average infestation of 13% (IAR, 1984; 1986b).

# Control measures

## Host plant resistance

Significant differences in the percentage of damaged leaves and number of eggs laid and frequency of oviposition among Arabica coffee cultivars were observed in a lathhouse experiment. Cultivars 7454, Dessu, Melko-CH2, 754 and 74140 were relatively more resistant to *L. caffeina* than the remaining cultivars as demonstrated by the low number of eggs laid and frequency of oviposition (Fig. 1), and the percentage of leaf damage. The results also indicated the existence of antixenosis resistance in *C. arabica* cultivars (Esayas and Chemeda, 2007b).

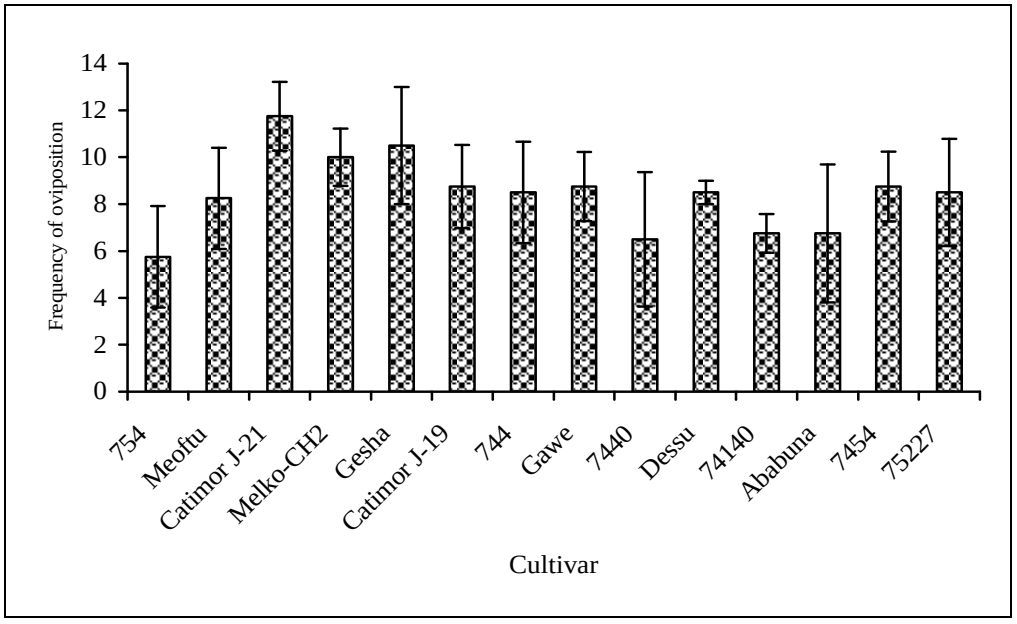


Fig. 1. Oviposition frequency of *L. caffeina* on leaves of *C. arabica* cultivars (Esayas and Chemeda, 2007b). Vertical bars = ± SEM.

## Biological methods

Blotch leaf miner is attacked by eight species of parasitoids (Million and Bayissa, 1986; IAR, 1987) among which *Aphidencyrtus aphidivorus*, *Pediobius caffeicola* Ferr. *Apanteles bordagei* Gir are the most abundant species (IAR, 1982; 1986b; 1987). Study in Jimma area on the relative abundance of the parasitoids indicated that *Aphidencyrtus aphidivorus* was the most abundant species with 72% parasitization (Table 12). It constitutes 70, 54.2 and 73% of the total parasitoids collected at Melko, Agaro and Metu, respectively. Similarly, *A. aphidivorus* is an important parasitoid of leaf miner in Kenya (Mugo, 1997).

Table 12. Relative abundance of leaf miner parasitoids in Jimma area (after IAR, 1982; IAR 1986a).

| Species | Population of parasitoid | |
|---|---|---|
| **Species** | **No** | **Percent** |
| *Aphidencyrtus aphidivorus* | 2733 | 72.02 |
| *Pediobius caffeicola* | 432 | 11.38 |
| *Chrysocharis lepelleyi* | 72 | 1.90 |
| *Cirrospilus after* | 66 | 1.74 |

## Chemical methods

Control of leaf miner is necessary during July to September. In order to estimate its population per tree, shaking a sample trees twice a week during this period has been recommended. If more than 30 moths flutter out from a single tree then the trees should be sprayed one week later with fenitrothion at the rate of 2 ml of 50% EC in 1 litre of water (Crowe and Tadesse, 1984).

## Coffee berry borer, *Hypothenemus hampei* (Ferrari)

The first occurrence of coffee berry borer in Ethiopia was reported by Davidson (1968). Later on, its incidence was reported from various parts of the country (Crowe and Tadesse, 1984; IAR, 1984; Million, 1987; 2001; Esayas *et al*., 2003; 2004).

## Biology of coffee berry borer

Studies on the biology and feeding behavior of the coffee berry borer were reported by Esayas *et al*. (2005). Incubation period of the egg ranged from 5-10 days with a mean of 6.5 $\pm$ 0.3 days. There are two larval instars for the female and one for the male, with an average developmental period of 17$\pm$0.5 days. Pupal period ranged from 5 to 9 days with a mean of 6.2 $\pm$ 0.3 days. Complete development period (egg to adult) took 24 to 43 days with a mean of 31.7 $\pm$ 0.8 days. Oviposition started at about 7-12 days after the emergence of female borer. Four sites of oviposition were identified, of which the female borer laid more eggs (44%) inside the parchment of the berry. The female laid two eggs per day and 32 eggs per female.

## Population dynamics

Population dynamics study conduced at Jimma showed that coffee berry borer population had a marked seasonal variation both on dry left over and fallen berries. Insects at all development stages were more abundant during January to August; however, this was highly associated with the availability of dry and left over berries. Moreover, weather factors showed a marked influence on the population dynamics of the borer (Esayas *et al*., 2004).

### Loss assessment

Surveys conducted at various coffee growing areas of the country showed that the borer inflicted up to 60% damage on dry left over coffee berries (Million, 2001; Esayas *et al*., 2004). Unlike in other countries where it attacks green, ripe and dry berries (Le Pelley, 1968; Baker, 1999), in Ethiopia, it attacks only dry left over and fallen berries. Damage on green berries was almost negligible (<1%) (Million, 2001; Esayas *et al*., 2003). However, it is important that the pest be monitored following the crop phenology to detect any deviation in its feeding behavior.

## Control measures

### Cultural control methods

Shade tree regulation and pruning can reduce the populations of the borer by creating unfavorable environmental conditions, and also exposing them to attack by the natural enemies of the borer (Crowe and Tadesse, 1984). Coffee berries should be collected as soon as they ripen (picking should be carried out at least every two weeks during fruiting peaks and every month at other times). All over-ripen or dry leftover and fallen berries should be collected after harvest and destroyed in order to deprive the borer the opportunity for breeding and leave little host for immigrating borers (Crowe and Tadesse, 1984; Million, 1987; Esayas *et al*. 2003; 2004).

### Scale insects

Out of the seven species of scale insects recorded on coffee in Ethiopia (Table 1), coffee cushion scale (*Stictococcus formicarius*) and green scale (*Coccus alpinus*) are potentially important pests. The former species is more important in Wellega, Metu and Mugi areas, while the latter species is common in many parts of western Haraghe causing the death of bearing branches (Million, 1987; 2000). From the assessment carried out at Bedessa sub-Station in western Haraghe, 89% of the CBD resistant selections were infested by the green scale (IAR, 1983). Both species are also present around Jimma, but at a low level of infestation (Million, 2000). The adult and nymphal stages of *C. alpinus* are attacked by four species of natural enemies, viz., *Aphytis* sp. (Hymenoptera: Bracconidae), *Coccophagus* sp. (Hymeno: Aphelinidae), *Hyperaspis abyssinica* (Hymeno: Aphelinidae) and *Metaphycus* sp. (Hymeno: Eulophidae) (Million and Bayissa, 1986; IAR, 1987).

### Thrips (*Diarthrothrips coffeae* Williams)

Coffee thrips is one of the potentially important insect pests of coffee. Thrips defoliated a large number of coffee trees at both the Jimma and Tepi areas

(IAR, 1972; 1997a). It was observed that thrips favored extended period of drought and disappear as soon as rain starts (Million, 2000). Fenitrothion was recommended for the control of thrips (Crowe and Tadesse, 1984).

## Other insect pests of coffee

### Serpentine leaf miner, *Cryphiomystis aletreuta* (Meyrick)

Serpentine leaf miner is a very common pest found in most coffee growing areas. It appears every year after the onset of the short rains affecting young leaves (Million, 2000). The life cycle of this insect studied at Gera showed that the average development period of egg, larva, pupa and adult were 8, 21, 21 and 3 days, respectively. It took about 56 days, on the average, to complete its life cycle (IAR, 1997b). The infestation level of the insect was low (0.15%) at Gera compared to that of Jimma (8.23%) (IAR, 1996a; 1996b). This insect is well suppressed by its natural enemies; however, it can easily build up to a damaging level in the absence of its natural enemies (Million, 1987).

### Coffee leaf skeletonizer, *Leucoplema dohertyi* (Warren)

The larvae feed on the underside of leaves, usually near the midrib eating every thing except the veins and the upper epidermis, leaving irregular lace-like patches in the leaf (Crowe and Tadesse, 1984). The developmental period of the egg, larva and pupa was 1, 3 and 3 weeks, respectively. Recent surveys conducted in southwestern Ethiopia showed mean leaf damage of 15.4% (Esayas, unpublished). At Melko only 3 % larval parasitization was recorded, which is low to check the pest in the field (IAR, 1984). The insect can be controlled by fenitrothion 50% E.C or fenithion 50% E.C (Crowe and Tadesse 1984).

### Cocoa stem borer (*Eulophonotus myrmeleon*)

There are six species of coffee stem/ branch boring insects known to exist in Ethiopia (Table 1). Cocoa stem borer is becoming an important pest occurring in many coffee growing regions of the country (Million, 1989; IAR, 1996c). Studies on some aspects of the biology of the insect revealed that the average development time of the larval, pupal and adult stages were 202.8 $\pm$ 12.4, 16.4$\pm$ 0.93 and 6.1 $\pm$ 0.5 days, respectively (Million, 1999b). The first sign of attack by the insect starts in early January. The first instar larva starts feeding on tertiary branches and gradually progress towards boring into large size branches, as it grows older. Consequently, the top main stem up to 1 meter and above can be attacked resulting in heavy loss of crop (Million, 1989; 1999b). Two parasitoids namely *Bathyaylax* sp. and an unidentified species were recorded. The former attacked 24% and the later 2.6% of the larvae collected. Scouting of a coffee field starting from early January was necessary. Branches with actively boring larva should be put together and burned, while branches

housing weak looking larva or already parasitized larva should be left on the tree to give way to the emergence of the parasitoid. Such practice reduced damage on the top part of the main stem by 75% (Million, 1989; IAR 1996c; Million, 1999b).

## Fruit flies

More than three species of fruit flies were reported infesting Arabica coffee in Ethiopia (Table 13). *Ceratitis rosa* Karsch, *C. capitata* (Wiedemann) and *Trirhithrum coffeae* Bezzi were the most frequently found and relatively abundant species (Mekuria *et al.*, 1995; Esayas, 2005). Observation on seasonal population variation at Melko/Jimma indicated that *C. rosa* was more abundant during the humid months of June to December, while *T. coffeae* was more abundant in the dry months of January to May (Mekuria *et al*., 1995). At Tepi the infestation by fruit flies ranged from 55± 2 to 58 ± 1, and the number of larvae ranged from 29 ± 2 to 33 ± 1 on five Arabica coffee varieties (Esayas, 2005).

Table 13. Fruit fly species distribution and relative abundance on coffee at various locations during 1988–1990 (after IAR, 1996a).

| **Locations** | **Mean percent fruit fly species** | | | |
|---|---|---|---|---|
| | ***Ceratitis rosa*** | ***Trirhitrum coffeae*** | ***Ceratitis capitata*** | **Unidentified sp** |
| Melko | 45.6 | 42.6 | 0.3 | 11.5 |
| Agaro | 45.2 | 44.3 | 0.0 | 9.5 |
| Gera | 78.5 | 13.5 | 0.0 | 8.5 |
| Metu | 77.7 | 15.2 | 0.0 | 7.1 |
| Tepi | 47.6 | 7.9 | 0.8 | 43.8 |
| Bebeka | 52.8 | 15.2 | 0.4 | 30.6 |
| Mugi | 46.6 | 45.6 | 0.4 | 7.4 |
| Mechara | 0.0 | 57.6 | 22.5 | 19.6 |
| Mean | 56.28 | 30.24 | 4.88 | 17.25 |

### Nursery insect pests

Several insect pests such as crickets, termites, cutworms, and chafer grabs are known to attack coffee seedlings in the nursery. Tortrix is also one of the nursery pests that attack young coffee seedlings. Brown tortrix, *(Tortrix dinota* Meyrick) and green tortrix (*Archips occidentalis* Wals.) are the two species recorded in Ethiopia (Million and Bayissa, 1986; Girma and Teame, 1994). It has been reported to cause severe damage to seedlings at various localities such as Yirga Chefe, Wonago, Gera, and Mana CIP nursery station (Girma and Teame, 1994; IAR, 1997a; 1997b; 1997c) (Table 14).

Hand collection and removal of infested leaves and shoots (the nests) was recommended as a control option for this pest (Girma and Teame, 1994), however, it might not be applicable to large-scale farms.

Table 14. Percentage of seedling losses due to tortrix at nursery sites in Ilubabor region (1992/93).

| Localities | Nursery site | Altitude (m) | Loss (%) | SEM |
|---|---|---|---|---|
| Gera | Wanja | 1920 | 14.57 | 0.58 |
| Goma | Echemo | 2000 | 8.64 | 0.33 |
| Goma | Bulbulo | 1600 | 2.22 | 0.22 |
| Mana | Inkulu | 1540 | 5.98 | 0.42 |
| Toba | Yachi | 1680 | 4.82 | 0.43 |
| Mean | | | 7.25 | |
| SEM | | | 2.10 | |

Source: Girma and Teame 1994.

## Conclusion and recommendations

- Studies conducted so far demonstrated the significant role of natural enemies in coffee pest management. It is, therefore, important that indigenous natural enemies be conserved and any farm activities which can affect the biological balance of natural enemies be avoided
- Some available botanicals such as *Milletia ferruginea*, *Chrysanthemum cinerariaefolium*, *Cinerariaefolium*, *Chenopodium ambrosiodes* and *Ekberga* sp. that showed promising result in the control of antestia bug under the laboratory conditions should be tested in field conditions
- Cultural practices such as shade tree regulation and pruning of coffee trees can reduce antestia bug and coffee blotch leaf miner population
- Shade tree regulation, pruning of coffee trees, proper picking of the crop and phytosanitary measures can reduce coffee berry borer population
- Egg masses of antestia can be collected by hand and hung in a basket away from the coffee plants. Parasitoids coming out of the eggs can fly in to the coffee while the antestia nymphs remain behind to die

- Chemical insecticides recommended for antestia are effective but due to the adverse effects of chemicals, priority should be given for non chemical control options
- Chlorpyrifos (Dursban) at 1.5l/ha, cypermetrin (Nurelle) at 1.125 l/ha, cypermetrin (Fenom 100) at 0.8 litre/ha, fenitrothion (Sumithion 50%) at 1.5 l/ha, Lamdacyhalothrin (Karate) at 0.4 l/ha with a spray volume of 500-1000 l/ha and trichlorfon 95% SP at 500 g/ha can be used to control antestia
- Fenitrothion at the rate of 2 ml of 50% EC in 1 litre of water can control coffee leaf miner
- A combination of insect natural enemies and physical methods (collection and burning of branches with actively boring larva of Cocoa stem borer and encouraging emergence of parasitoids from parasitized larva on the tree) can reduce damage to the top part of the main stem significantly

## Gaps and challenges

- Studies on current status of insect pests of coffee and their natural enemies under different ecology and production systems
- Proper studies on biology, rearing and ecological requirements of the identified potential natural enemies so that they can be used in biological control of coffee pests such as augmentation
- The use of biopesticides based on natural products (botanicals) and entomopathogenic fungi and nematode are among the least considered in coffee pest management
- Search for resistant/ tolerant varieties against major pests of coffee
- Development of IPM for insect pests of coffee.
- In spite of the significant role of tea and spices in the economy of the country, there is little or no information on pests and their natural enemies of these crops

## Future

- Biological control ought to be very promising for coffee insect pest management because coffee trees provide ideal condition for natural enemies. It is a bright prospect to use indigenous natural enemies for biological control of coffee insect pests
- As Ethiopia is the centre of origin and diversity of Arabica coffee, there is a potential to find resistant/tolerant varieties against major insect pests of coffee in Ethiopia
- Biopesticides based on botanicals and microbial control agents are one of the potential options for coffee pest management.
- Development of IPM of major coffee pests

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# Review of Research on Insect Pests of Fiber Crops in Ethiopia

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## Introduction

Cotton (*Gossypium* sp.), kenaf (*Hibiscus cannabinus*) and sisal (*Agave sisalina*) are three of the fiber crops grown in Ethiopia among which cotton is the most important (Bedada, 1987). Although cotton is grown principally for its fiber, the seed is also used as a source of cooking oil and the cake is used as livestock feed and fertilizer (EARO, 2000a).

Kenaf was produced in the former State Farms, Bir, Beles and Ukie in the early 1980's (Asfaw, 1985), but this days the production of kenaf ceased for various reasons.

Sisal was produced on large hectares of land around Shashemene and Awassa as a raw material for the fiber factories in the 1960's, but currently the crop occupies small area of land at Awassa and the volume of production is not known. There is no research information on sisal in Ethioipa.

Insect pests are among the major constraints to the production of these crops because of significant yield losses and quality degradation they cause. However, infestation levels of specific pests vary from season to season and from place to place. Although numerous insect pests are known to infest cotton, only a few are economically important (Table 1). According to Tsedeke (1982), Alemayehu (1983) and Alemayehu and Ababu (1986), seed cotton yield losses caused by bollworms was 36-60%, by sucking pests in general was 22%, and by the cotton aphid alone was about 14% in irrigated cotton.

On kenaf a few species of flea beetles especially *Podagrica* spp. are widely distributed and abundant throughout the growing season causing heavy damage from seedling to harvest (Table 2). Seed and stainer bugs are important at maturity posing serious damage by sucking the contents of the seed. A number of entomological researches were carried out on cotton and kenaf in Ethiopia and results were reviewed by Tsedeke (1982) and Alemayehu and Ababu (1986). This paper reviews research results generated since then.

# Research findings

## Pests recorded

Results of surveys conducted from 1986/87 to 1995/96 indicated that the African bollworm (ABW) (*Helicoverpa armigera*), aphid (*Aphis gossypii*), leaf worm (*Spodoptera litoralis*), pink bollworm (*Pectinophora gossypiella*), jassid (*Empoasca lybica*), whitefly (*Bemisia tabaci*) and thrips (*Thrips tabaci*) were recorded as key pests. The list of important insect pests of cotton and kenaf is presented in Tables 1 and 2, respectively.

Table 1. Insect pests recorded on cotton in Ethiopia.

| Scientific name | Common name | Status | References |
|---|---|---|---|
| **Acari** | | | |
| **Tarsonemidae** | | | |
| *Polyphagotarsonemus latus* (Banks) | Yellow tea mite | Sporadic | 15, 39 |
| **Tetranychidae** | | | |
| *Oligonychus coffeae* (Nietn.) | Red coffee mite | Rare | 27 |
| *Tetranychus cinnabarinus* (Boisd.) | Cotton red mite | Major | 15, 16 |
| **Coleoptera** | | | |
| **Buprestidae** | | | |
| *Julotis caillandi* Latr. | - | Rare | 21 |
| *Sphenoptera patrizii* Olenb. | | | 17, 27 |
| *Sphenoptera trispinosa* Klug. | Cotton stem borer | Minor | 16, 21 |
| **Cerambycidae** | | | |
| *Tragiscoschema nigroscriptum* Farim. | Cotton stem girdler | Minor | 16 |
| **Chrysomelidae** | | | |
| *Podagrica pallida* (Jac.) | Abutilion flea beetle | Minor | 28 |
| *Podagrica pallidicolor* Pic. | Cotton flea beetle | Major | 17, 27 |
| *Podagrica puncticollis* Wse. | Cotton flea beetle | Major | 16, 24, 27 |
| *Podagrica uniformis* Jac. | Cotton flea beetle | Major | 17 |
| *Syagrus rugiceps* Lef. | | | 27 |
| **Curculionidae** | | | |
| *Tanymecus* sp. | Seedling weevil | Minor | 17 |
| **Meloidae** | | | |
| ***Mylabris*** sp. | Pollen beetle | Minor | 17 |

Table 1. Contd.

| Scientific name | Common name | Status | References |
|---|---|---|---|
| **Tenebrionidae** | | | |
| *Adesmia reticulate* Plug | | | 17, 39 |
| *Anemia sardoa* Gene | Darkling beetle | Minor | 17, 39 |
| *Goncephalum tenebroids* | Dusty brown beetle | Minor | 17, 39 |
| **Scarabaeidae** | | | |
| *Schizonycha* sp. | Chaffer grub | Minor | 39 |
| **Hetroptera** | | | |
| **Lygaeidae** | | | |
| *Oxycarenus hyalinipennis* (Costa) | Cotton seed bug | Major | 16, 17, 27 |
| *Oxycarenus* sp. | Cotton seed bug | Minor | 27 |
| *Bemisia tabaci* (Genn.) | Tobacco whitefly | Major | 17 |
| **Aphididae** | | | |
| *Aphis frangulae* Koch | - | Minor | 17 |
| *Aphis gossypii* Glov. | Cotton aphid | Major | 16, 18, 28 |
| **Coccidae** | | | |
| *Coccus hesperidum* L. | Soft brown scale | Minor | 39 |
| **Cicadellidae** | | | |
| *Empoasca fascialis* (Jac.) | Cotton jassid | Major | 8 |
| *Empoasca lybica* (De Berg.) | Cotton jassid | Major | 13, 16, 39 |
| **Pseudococcidae** | | | |
| *Ferrisia virgata* (Ckll.) | Striped mealy bug | Minor | 39 |
| *Paracoccus* sp. | Citrus mealy bug | Minor | 39 |
| **Isoptera** | | | |
| **Termitidae** | | | |
| *Amitermes sciangallorum* Ghid. | Termite | Minor | 13, 39 |
| *Anoplotermesi* sp. | Termite | Minor | 39 |
| **Lepidotera** | | | |
| **Gelechiidae** | | | |
| *Pectinophora (platyedra) gossipiella* Saund.) | Pink bollworm | Major | 1, 3, 16, 25, 39 |
| **Gracillariidae** | | | |
| *Acrocercops bifasciata* Wlsm. | Cotton leaf miner | Minor | 16, 39 |

Table 1. Contd.

| Scientific name | Common name | Status | References |
|---|---|---|---|
| **Noctuidae** | | | |
| *Agrotis segetum* Schiff | Common cutworm | Minor | 21 |
| *Anomis (= Cosmophila) flava* F. | Cotton semi-looper | Minor | 16, 21 |
| *Chrysodexis (=Plusia) acuta* (Wlk.) | - | Minor | 39 |
| **Noctuidae** | | | |
| *Diparopsis* sp. | Sudan bollworm | Major | 1, 2, 21, 39 |
| *Earias biplaga* Wlk | Spiny bollworm | Minor | 1, 2, 29, 30 |
| *Earias insulana* Boisd. | Spiny bollworm | Moderate | 1, 2, 29, 30 |
| *Helicverpa armigera* (Hb.) | African bollworm | Major | 1, 2, 16, 21, 29, 39 |
| *Spodeptera exempta* (Wlk.) | Armyworm | Minor | 21 |
| *Spodeptera (= Laphygma) exigua* (Bb.) | Lesser armyworm | Major | 15, 16, 17 |
| *Spodeptera (= Prodenia) littoralis* (Boisd.) | Cotton leaf worm | Major | 15, 16, 21 |
| *Xanthodes graellisii* (Festh.) | Cotton worm | Minor | 15, 16 |
| **Olethreutidae** | | | |
| *Cryptophlebia leucotreta* | False codling moth | Minor | 15, 16 |
| **Pyralidae** | | | |
| *Sylepta derogata* (F.) | Cotton leaf roller | Minor | 15, 16 |
| **Orthoptera** | | | |
| **Acrididae** | | | |
| *Acrida bicolar* (Thumb) | Grass hopper | Minor | 28 |
| *Anacridium melanothodon* Wlk. | Tree locust | Minor | 17 |
| *Catantops pinguis* Burm. | Grass hopper | Minor | 17 |
| *Ornitacris* sp. | Grass hopper | Minor | 17 |
| **Gryllidae** | | | |
| *Gryllus (Lyogryllus) bimaculathus* (Deg.) | Two-spotted cricket | Minor | 17, 37, 38 |
| *Scapsipedus marginatus* (Afr and Brann.) | Grass hopper | Minor | 28, 37, 38 |
| *Pyrgomorphidae* | | | |
| *Pyrgomorpha conica* (01.) | Cotton grass hopper | Minor | 16 |

Table 1. Contd.

| Scientific name | Common name | Status | References |
|---|---|---|---|
| **Thysanoptera** | | | |
| **Thripidae** | | | |
| *Caliothrips lupirus (*Pries) | Cotton thrips | Major | 16 |
| *Caliothrips sudanensis (*Bagn. and Cam.) | Bean thrips | Major | 16, 27 |
| *Mycterothrips acaciae* | Acacia thrips | Minor | 39 |
| *Selenothrips indicus* Bagn. | Thrips | Minor | 17 |

Table 2. Insect pests recorded on kenaf in Ethiopia.

| Scientific name | Common name | Status | References |
|---|---|---|---|
| **Coleoptera** | | | |
| **Chrysomelidae** | | | |
| *Podagrica* spp. | Flea beetle | Major | 30, 31, 39 |
| **Meloidae** | | | |
| *Mylabris* spp. | Pollen beetle | Moderate | 32, 39 |
| **Hetroptera** | | | |
| **Lygaeidae** | | | |
| *Oxycarenus* sp. | Seed bug | Major | 31, 39 |
| **Pyrrhocoridae** | | | |
| *Dysdercus* spp. | Stainer bugs | Major | 31, 39 |
| *Aphis gossypii/maidis* | Aphid | Moderate | 31, 39 |
| **Pentatomidae** | | | |
| *Nezera virdula* | Stink bug | Moderate | 32, 39 |
| **Isoptera** | | | |
| **Termitidae** | | | |
| *Microterms* spp | Termites | Moderate | 31, 39 |
| **Orthoptera** | | | |
| **Gryllidae** | | | |
| Unidentified species | Grasshoppers | Moderate | 32, 39 |

# Basic studies

## Biology of the African bollworm

The biology of the African bollworm studied in the laboratory at Werer Research Center showed that egg development took 2.2 $\pm$ 0.7 days, while the total larval period was 14.7 $\pm$ 0.8 days. The pre-pupal period took 1.5 $\pm$ 0.4 days. Pupation took place in the soil (at the depth of 1-3 cm) and lasted 7-12 days, 9.92 $\pm$ 1.1 on the average (Table 3). Of the 1883 pupae studied, 46.3% emerged as healthy moths. The proportion of deformed moths was 16.3%,

while death at emergence accounted for 4.1%. Regarding pupal mortality, about 15.6% was due to diseases and about 15.7% was due to desiccation. About 12% of the adults emerged within 7 days after pupation, while 31% emerged 8 days after pupation. Only 4% emerged after 11 to 12 days of pupation. The male to female ratio was 1:1.11. The female moth started egg laying 3 to 4 days (average 2.8 $\pm$ 0.3) after emergence and it was extended for 4 to 5 days. The number of eggs laid per female per day was 50, the total ranged from 8 to 980; the average was 242.2 eggs. Over 47% of the eggs were infertile. Among the mortality factors, infertility and desiccation were estimated to contribute 20-30% of egg population reduction. Disease infection was the major factor for the mortalities of larvae, pre-pupae, and pupae. In addition, desiccation decreased the survival of pupae by 15-30%, which increased to 40% when the room temperature rose to $37^0$C and above. Under temperatures above $35^o$C, fecundity decreased and even the surviving adults could not depart after mating and died fixed. From the life table study, the net reproductive rate ($R_o$) of ABW was 77.98 and the intrinsic rate of increase (r) was 0.78. The total K-value was 0.85 and the generation time was 27.5 days (Geremew, 2004).

Table 3. Biology of ABW in the laboratory at Werer (after Geremew, 2004).

| **Development stages** | | **Duration (Days)** | |
|---|---|---|---|
| | | **Range** | **Mean $\pm$ SE** |
| Egg | White | 1.0 - 1.5 | 1.21 $\pm$ 0.21 |
| | Brown | 0.5 - 1.5 | 0.62 $\pm$ 0.25 |
| | Black | 0.2 - 1.0 | 0.40 $\pm$ 0.19 |
| Total egg period | | 1.7 - 4.0 | 2.23 + 0.65 |
| Larvae | 1st instar | 1.5 - 2.5 | 2.17 $\pm$ 0.18 |
| | 2nd Instar | 1.8 - 2.5 | 2.14 $\pm$ 0.18 |
| | 3rd Instar | 1.5 - 2.0 | 1.58 $\pm$ 0.15 |
| | 4th Instar | 2.0 - 2.5 | 1.94 $\pm$ 0.13 |
| | 5th Instar | 2.0 - 3.0 | 2.07 $\pm$ 0.23 |
| | 6th Instar | 3.0 - 4.0 | 3.15 $\pm$ 0.31 |
| Total larval period | | 11.8 - 16.5 | 14.71$\pm$ 0.81 |
| Per-pupa | | 1.0 - 2.0 | 1.50 $\pm$ 0.40 |
| Pupa | | 7.0 - 12.85 | 9.92 $\pm$ 1.05 |
| Adult | | 6.0 - 10.0 | 7.35 $\pm$ 1.73 |
| Total period (egg to adult) | | 27.5 - 45.0 | 34.05 $\pm$ 0.48 |

## Population dynamics of bollworms and armyworms

Activities of cotton bollworms (ABW, the Sudan and Spiny bollworms) and defoliators (African armyworm, lesser armyworm, and cotton leaf worm) were monitored in the field using pheromone and light traps at Werer Research Center from 1980-1992. Pheromone traps were used only for monitoring the

African armyworm. Moths caught in the light and pheromone traps are presented in Tables (4, 5, 6, 7, and 8). The data indicated that the African bollworm adult catch was high in June, July, and August. Similarly, in these months field counts of larvae population were also above the economic threshold level, which necessitated pesticide application. In the 1985/86 season, the population reached 1708 adults per year, while the lowest was in 1982/83 season when only 9 adults were caught in the whole year (Table 4). In most years, the population of adults and larvae of the African bollworm started to decline in October (IAR, 1987).

Table 4. Light trap catches of the African bollworm from 1980 to 1992 seasons at Werer Research Center (IAR, 1990, 1996).

| Year | Month | | | | | | | | | | | Annual total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | A | M | J | J | A | S | O | N | D | J | F | |
| 1980/81 | - | 0 | 29 | 350 | 96 | 10 | 6 | - | - | 0 | - | - | 491 |
| 1981/82 | 1 | 0 | 29 | 335 | 83 | 5 | 7 | 1 | - | - | 0 | 0 | 461 |
| 1982/83 | 0 | - | 0 | - | 2 | 0 | 2 | 3 | 0 | 0 | 1 | 1 | 9 |
| 1983/84 | 4 | 0 | 0 | 0 | 1 | 16 | 5 | 0 | 0 | 0 | 0 | 0 | 26 |
| 1984/85 | 1 | 0 | 0 | 0 | 6 | 8 | 34 | 9 | 1 | 3 | 0 | 1 | 63 |
| 1985/86 | 6 | 0 | 3 | 1231 | 172 | 209 | 69 | 7 | 3 | 0 | 3 | 5 | 1708 |
| 1986/87 | 1 | 0 | 2 | 29 | - | - | 1 | 4 | 2 | 4 | 1 | 3 | 47 |
| 1987/88 | 1 | 1 | 4 | 84 | 22 | 39 | 0 | 5 | 0 | 0 | 1 | 0 | 157 |
| 1988/89 | 0 | 0 | 0 | 11 | 6 | 0 | 41 | 3 | 2 | 2 | 4 | 1 | 70 |
| 1989/90 | 0 | - | 1 | 14 | 30 | 7 | - | 0 | 3 | 0 | 5 | 0 | 60 |
| 1990/91 | - | - | 25 | 34 | 3 | 49 | 19 | 4 | 3 | 5 | 2 | 0 | 144 |
| 1991/92 | 1 | 0 | 0 | 42 | 103 | 9 | - | 0 | 1 | 3 | 6 | 3 | 168 |

The Sudan bollworm catch was high in March, April and May and declined in June, July and August. Then it tended to increase again starting from September (Table 5). Generally, the Sudan bollworm population was high in the years between 1984/85 and 1988/89 (IAR, 1987).

The spiny bollworm appeared late in the season and the population was low in the area compared to the African bollworm and the Sudan bollworm. The population reached peaks from October to December and started to decline in January. The highest number of spiny bollworms was recorded in 1989/90 and 1990/91 seasons (Table 6).

Table 5. Light trap catches of the Sudan bollworm from 1980 to 1992 seasons at Werer Research Center (IAR, 1990, 1996).

| Year | Month | | | | | | | | | | | | Yearly total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | A | M | J | J | A | S | O | N | D | J | F | |
| 1980/81 | - | 4 | 17 | 5 | 0 | 4 | 1 | - | - | 1 | - | - | 32 |
| 1981/82 | 0 | 4 | 21 | 3 | 0 | 0 | 0 | 2 | - | - | 0 | 0 | 30 |
| 1982/83 | 1 | - | 0 | - | 0 | 0 | 0 | 1 | 23 | 38 | 0 | 2 | 66 |
| 1983/84 | 11 | 49 | 325 | 48 | 5 | 5 | 26 | 4 | 3 | 5 | 4 | 20 | 505 |
| 1984/85 | 22 | 11 | 65 | 30 | 11 | 18 | 568 | 281 | 101 | 139 | 5 | 8 | 1259 |
| 1985/86 | 169 | 101 | 387 | 32 | 4 | 19 | 56 | 117 | 292 | 87 | 63 | 191 | 1512 |
| 1986/87 | 440 | 433 | 149 | 0 | - | - | 3 | 150 | 154 | 197 | 40 | 132 | 1698 |
| 1987/88 | 40 | 950 | 261 | 11 | 2 | 0 | 6 | 26 | 78 | 11 | 63 | 24 | 1472 |
| 1988/89 | 47 | 4 | 6 | 1 | 0 | 0 | 7 | 55 | 102 | 94 | 90 | 28 | 434 |
| 1989/90 | 60 | - | 9 | 5 | 5 | 3 | - | 15 | 18 | 81 | 81 | 158 | 435 |
| 1990/91 | - | - | 48 | 0 | 0 | 0 | 6 | 9 | 47 | 64 | 90 | 39 | 303 |
| 1991/92 | 61 | 0 | 1 | 0 | 0 | 0 | 13 | 148 | 155 | 133 | 13 | 23 | 547 |

Table 6. Light trap catches of *Earias insulna* and *E. biplaga* from 1980 to 1992 seasons at Werer Research Center (IAR, 1990, 1996).

| Year | Spp | Month | | | | | | | | | | | | Year total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M | A | M | J | J | A | S | O | N | D | J | F | |
| 1980/81 | Ei | - | 0 | 0 | 0 | 1 | 0 | 2 | - | - | 0 | - | - | 3 |
| | Eb | 0 | 0 | 0 | 0 | 0 | 0 | 1 | - | - | 0 | - | - | 1 |
| 1981/82 | Ei | 0 | 0 | 0 | 0 | 1 | 0 | 3 | 1 | - | - | 0 | 0 | 5 |
| | Eb | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | - | 0 | 1 | 1 |
| 1982/83 | Ei | 0 | - | 0 | - | 0 | 0 | 0 | 0 | 3 | 2 | 0 | 0 | 5 |
| 1983/84 | Ei | 0 | 0 | 1 | 2 | 0 | 0 | 1 | 4 | 3 | 0 | 0 | 0 | 11 |
| 1984/85 | Ei | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 3 |
| 1985/86 | Ei | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 4 | 0 | 6 |
| 1986/87 | Ei | 0 | 0 | 0 | 0 | - | - | 0 | 25 | 4 | 3 | 0 | 0 | 32 |
| 1987/88 | Ei | 0 | 6 | 29 | 9 | 2 | 3 | 0 | 11 | 19 | 1 | 0 | 1 | 81 |
| | Eb | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 6 |
| 1988/89 | Ei | 1 | 0 | 0 | 4 | 4 | 0 | 1 | 10 | 12 | 23 | 14 | 1 | 69 |
| | Eb | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 5 | 6 | 0 | 0 | 13 |
| 1989/90 | Ei | 2 | - | 1 | 3 | 4 | 2 | - | 9 | 26 | 30 | 19 | 11 | 107 |
| 1990/91 | Ei | - | - | 62 | 49 | 1 | 5 | 8 | 32 | 17 | 12 | 38 | 12 | 236 |
| 1991/92 | Ei | 0 | 1 | 1 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | 2 |
| | Eb | 0 | 2 | 1 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | 3 |

Ei = *Earias insulana*, Eb = *Earias biplaga*, - = not observed.

The population of *Spodoptera* spp. was low in most years monitored, the peaks were in the periods from 1983-1986 (Table 7).

Table 7. Light trap catches of *Spodoptera* spp. from 1981 to 1992 at Werer Research Center.

| Year | Spp. | Month | | | | | | | | | | | | Year total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M | A | M | J | J | A | S | O | N | D | J | F | |
| 01981/82 | A | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 6 | 0 | 0 | 7 |
| | B | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 1982/83 | A | 0 | - | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | B | 0 | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 3 |
| 1983/84 | A | 0 | 0 | 104 | 0 | 5 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 114 |
| | B | 0 | 2 | 4 | 11 | 7 | 11 | 47 | 22 | 21 | 13 | 3 | 0 | 141 |
| | C | 0 | 2 | 4 | 4 | 0 | 10 | 42 | 5 | 2 | 4 | 3 | 0 | 76 |
| 1984/85 | A | 94 | 49 | 19 | 3 | 10 | 0 | 10 | 5 | 0 | 0 | 6 | 29 | 225 |
| | B | 11 | 13 | 16 | 4 | 7 | 0 | 39 | 29 | 1 | 30 | 12 | 21 | 183 |
| | C | 0 | 0 | 0 | 2 | 5 | 1 | 10 | 59 | 2 | 9 | 0 | 4 | 182 |
| 1985/86 | A | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 1 | 0 | 0 | 5 |
| | B | 85 | 0 | 5 | 18 | 22 | 13 | 11 | 29 | 47 | 5 | 135 | 76 | 446 |
| | C | 37 | 0 | 1 | 29 | 17 | 19 | 49 | 14 | 15 | 1 | 20 | 58 | 260 |
| 1986/87 | A | 0 | 1 | 2 | 4 | - | - | 0 | 0 | 0 | 0 | 0 | 0 | 7 |
| | B | 29 | 0 | 5 | 0 | - | - | 0 | 3 | 3 | 10 | 1 | 29 | 80 |
| | C | 0 | 0 | 1 | 0 | - | - | 3 | 55 | 3 | 1 | 0 | 1 | 64 |
| 1987/88 | A | 0 | 1 | 1 | 1 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 7 |
| | B | 0 | 40 | 24 | 8 | 0 | 0 | 0 | 0 | 0 | 1 | 16 | 2 | 91 |
| | C | 0 | 4 | 9 | 13 | 1 | 11 | 2 | 1 | 2 | 3 | 12 | 0 | 58 |
| 1988/89 | A | 0 | 0 | 13 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 32 |
| | C | 1 | 0 | 0 | 0 | 0 | 0 | 159 | 1 | 18 | 0 | 2 | 1 | 182 |
| 1989/90 | A | 0 | - | 0 | 0 | 0 | 0 | - | 0 | 1 | 0 | 0 | 0 | 1 |
| | C | 0 | - | 0 | 2 | 8 | 0 | - | 6 | 7 | 6 | 0 | 0 | 29 |
| 1990/91 | A | - | - | 31 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 35 |
| | B | - | - | 27 | 4 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 33 |
| | C | - | - | 32 | 5 | 1 | 9 | 47 | 39 | 7 | 39 | 0 | 0 | 179 |
| 1991/92 | A | - | 0 | 0 | 4 | 0 | 0 | - | 0 | 0 | 0 | 0 | 0 | 4 |
| | B | 21 | 0 | 2 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 | 5 | 28 |
| | C | 8 | 0 | 18 | 0 | 0 | 6 | - | 0 | 3 | 3 | 16 | 2 | 56 |

Source: IAR, 1990, 1996. A= *exempta*, B= *exegua*, C= *litoralis* species

They were more abundant in September and October, but it was common to observe theses insects throughout the year when conditions were favorable for their development. The three species took the lead position interchangeably, but in most cases *S. exigua* and *S. litoralis* were dominant (IAR, 1987).

Monthly pheromone trap catches of the pink and spiny bollworms, cotton leaf worm and the African armyworm are presented in Table 8. The pink bollworm was trapped from June to October and high numbers were recorded in July and August. The population of the spiny bollworm was low and observed only in June and August. The armyworm population was prevalent in the months of June, July and August with the peaks in June and July (Table 8).

Table 8. Pheromone trap catches of insect pests in 1991 at Werer.

| Month | Pink Bollworm | Spiny bollworm | Cotton leaf worm | Army worm |
|---|---|---|---|---|
| June | 65 | 5 | 58 | 685 |
| July | 158 | 0 | 33 | 92 |
| August | 138 | 4 | 62 | 8 |
| September | 75 | 0 | 34 | 0 |
| October | 43 | 0 | 0 | 0 |

Source: IAR, 1996.

Studies on the effect of cumulative degree-days conducted from 1986-1992 to predict the emergence patterns of the African and pink bollworms by monitoring the daily maximum and minimum temperatures and by visual field inspections, indicated the presence of a relationship between heat units and the date of the first adult appearance in the field (Ermias Shonga, pers. observation). The correlation of the total cumulative heat units with the first appearance date of the insects revealed the physiological development time of the insect concerned, which could be used for accurate forecasting than calendar dates. The average cumulative heat units required for the emergence of the African and pink bollworms were 2569.4 and 2538.42 degree-days, respectively (Table 9). In field assessments and light trap catches, it was found that the most frequent time of first appearance of the insects was June. In practice these insects start to appear in the area in June, pink bollworms appear one week later than the African bollworm.

Table 9. African bollworm and pink bollworm first appearance of eggs in the field and trap catch dates and their cumulative degree-days.

| Year | Insect | Date of first egg observed | Cumulative degree days | Date of first catch in light trap | Cumulative degree days |
|---|---|---|---|---|---|
| 1986/87 | ABW | 18/6/86 | 2472.2 | 25/6/86 | 2586.5 |
| | PBW | 26/6/86 | 2599.5 | 25/7/86 | 3551.2 |
| 1987/88 | ABW | 6/7/87 | 2795.5 | 02/6/87 | 2124.1 |
| | PBW | No | - | 13/5/87 | 1809.3 |
| 1988/89 | ABW | 21/6/88 | 2753.9 | 5/6/87 | 2444.6 |
| | PBW | 4/8/88 | 3494.6 | No | - |
| 1989/90 | ABW | 26/6/89 | 2441.2 | 27/6/89 | 2458.5 |
| | PBW | 21/6/89 | 2345.6 | 28/6/89 | 2476.3 |
| 1990/91 | ABW | 12/6/90 | 2394.6 | 1/6/90 | 2172.4 |
| | PBW | 19/6/90 | 2537.9 | 30/5/90 | 2131.7 |
| 1991/92 | ABW | 10/6/91 | 2442.4 | 20/6/91 | 2634.9 |
| | PBW | 1/10/91 | 4252.9 | NT | - |
| 1992/93 | ABW | 20/6/92 | 2686.5 | NT | - |
| | PBW | No | - | NT | - |

ABW= African bollworm, PBW= pink bollworm, NT = trap not installed, - = Not observed

## Diapauses of the African and pink bollworms

In order to determine the source of bollworms' infestation and to devise management strategies, soil sieving, emergence, pupation and laboratory perplex cage trials were conducted. The result showed that only few exuvials of ABW pupae were located at 4-6 cm soil depth in previous cotton fields. However, no emerging adults were observed from field emergence and pupation cages. The larvae inside matured bolls, placed in the cages neither diapaused nor emerged as adults. On the other hand, the pheromone and light trap catch data showed that there were no immigrating ABW adults. Therefore the source of infestation in the area for the African bollworm was not known (IAR, 1987; Ababu and Girma, 1990). Cotton seeds were separated from the lint and cut opened to examine for the presence of diapausing pink bollworm larvae. Ten thousand cotton seeds were examined each season from 1986 to 1989, and only 33 diapausing larvae were recorded.

No pink bollworm adults were emerged from young bolls buried and field cages placed on previous season cotton fields. However, from the bolls placed inside perplex cages the pink bollworm adult emergence period varied from 16 to 320 days. About 74 to 94% of the adults emerged within 16 to 53 days, while the rest lasted 70 to 320 days of storage (Table 10). Therefore, the only possible place where PBW diapauses could be cotton seeds in stores (IAR, 1987; 1990).

Table 10. Number of Pink bollworm adults emerged from diapausing larvae in perplex cages in the laboratory (IAR, 1990, 1996).

| Larval resting period (days) | Number of PBW adults emerged each year | | | | | |
|---|---|---|---|---|---|---|
| | 1988 | Adult emerged (%) | 1989 | Adult emerged (%) | 1990 | Adult emerged (%) |
| 16 -22 | 182 | 43.54 | 95 | 6.09 | 2381 | 93.48 |
| 39 -53 | 156 | 37.32 | 1061 | 68.01 | 22 | 0.86 |
| 70 -84 | 7 | 1.67 | 19 | 1.22 | 11 | 0.43 |
| 98 -114 | 20 | 4.78 | 56 | 3.59 | 55 | 2.16 |
| 129 -145 | 28 | 6.70 | 93 | 5.96 | 39 | 1.53 |
| 159 -175 | 6 | 1.43 | 63 | 4.04 | 38 | 1.49 |
| 178 -197 | 14 | 3.34 | 49 | 3.14 | 1 | 0.0004 |
| 220 -228 | 1 | 0.24 | 73 | 4.68 | - | - |
| 251 -259 | 4 | 0.96 | 34 | 2.18 | - | - |
| 289 | - | - | 9 | 0.57 | - | - |
| 320 | - | - | 8 | 0.51 | - | - |

- = not observed

## Host range of cotton whitefly

A number of both wild and cultivated plants were recorded as hosts for the cotton whitefly (Table 11). Out of the thirty six different host plants listed, velvet leaf (*Abutilon* sp.), pig weed (*Amaranthus* sp.), wild lettuce (*Lactuca* sp.) and morning glory (*Ipomea* spp.) were the most important host plant species throughout the localities surveyed (Brhane, 1987; Alemayehu, 1988). Among the crops grown at Werer during the main season (cotton, groundnut, sesame, kenaf, and maize), cotton was the most preferred host. In the cool season (October to February), wheat, maize, safflower, sesame and tomato were grown as double cropping, among which tomato was the most susceptible, while wheat was not infested at all (IAR, 1990).

Table 11. Host plants of whitefly recorded in the Awash Valley during the 1983/84 season.

| Common name | Scientific name | Common name | Scientific name |
|---|---|---|---|
| Pig weed | *Amaranthus sp.* | - | *Rhyncosia minima* |
| Spider flower | *Gynandropsis gynandra* | Velvet leaf | *Abutilon indicum* |
| Wondering jew | *Commelina benghalensis* | Velvet leaf | *Abutilon theopratis* |
| Wild lettuce | *Lactuca spp.* | Cotton | *Gossypium hirsutum* |
| Cocklebur | *Xanthium strumarium* | Kenaf | *Hibiscus cannabinus* |
| Field bind weed | *Convolvulus arvensis* | Pickly sida | *Sida alba* |
| Morning glory | *Ipomea aquatica* | Sesame | *Sisamum indicum* |
| Sweet potato | *Ipomea patatas* | Endod | *Phytolacca dodecandra* |
| Cabbage | *Brassica oleraceae* | Black bind weed | *Polygonum convolvulus* |
| Pumpkin | *Cucubita popo* | Smart weed | *Polygonum pennsylvanicum* |
| Water melon | *Citrus vulgaris* | Knot weed | *Polygonum senegalense* |
| Spurge | *Euphorbia geniculata* | Pepper | *Capsicum annum* |
| Castor oil | *Ricinus communis* | Jimson weed | *Datura stramonium* |
| Groundnut | *Arachis hypogea* | Tomato | *Lycopersicum esculentum* |
| Cassia | *Cassia sp.* | Tobacco | *Nicotiana tabacum* |
| Jacaranda | *Jacaranda spp.* | Sodom apple | *Solanum incunam* |
| Haricot bean | *Phaseolus vulgaris* | Black night shade | *Solanum nigrum* |
| Flamboyant tree | *Poinceana regia* | Potato | *Solanum tuberosum* |

Source: Brhane, 1987.

## Population dynamics of cotton whitefly

During the 1987/88 and 1998/99, the population dynamics of whitefly was studied using yellow sticky traps and field counts of immature stages on young leaves ($5^{th}$ to $7^{th}$ node) of cotton variety Acala SJ2. Different life stages of the whitefly (adult, nymph, and pupa) were observed throughout the seasons at Werer Research Center on crops, weeds and shrubs. Maximum whitefly adult catch and nymph counts were recorded in July and the lowest in May (Table 12). Trace of adult whitefly catches extended all year round.

Distribution of whitefly studied in the Awash Valley in the 1983/84 crop seasons indicated that in areas where the annual temperature was high (39 $^{o}$C) and the rainfall was very low (1.5 mm) whitefly infestation reached 95-99% in the farms at Dubti, Dit-Bahri, Mille and Assaita. Whereas, infestation in the Middle Awash was relatively low (10-35%). This might be due to the occurrence of high rainfall (28 mm) and lower temperature (34 $^{o}$C) in July and August (Table 12).

Table 12. Mean monthly catches of whitefly at Werer in 1998.

| Months | No. of adults/trap | No. of nymphs/leaf |
|---|---|---|
| May | 27.4 | 0 |
| June | 84.3 | 2.1 |
| July | 435.3 | 12.8 |
| August | 126.4 | 5.5 |
| September | 105.5 | 1.2 |

Source: Gerling *et. al*., 2000 and EARO, 2000b.

## Insecticide resistance

Six African bollworm populations (Arbaminch, Dubti, Dukem, Humera, Werer and Zemea) collected from cotton, tomato and chickpea were evaluated for susceptibility to endosulfan, lamda-cyhalotrin, methomyl and profenofos using topical application, larval immersion and square dipping techniques. The topical application study with the third instar larvae showed that the Arbaminch population was resistant to endosulfan, and the Dubti population was resistant to lamda-cyhalotrin (Table 13).

Larval immersion studies conducted with Calofos 250 EC/ULV, Ethiosulfan 35% EC and Karate 5% EC indicated that Calofos at eight times lower rate ($3.125 \times 10^{-4}$ g a. i/ml) than the field rate of $2.5 \times 10^{-3}$ g a.i/ml caused 99.3% mortality. Similarly, Karate caused 98.3% mortality at the rate of $6.25 \times 10^{-5}$ g a.i/ml, which was eight times lower than the field rate of $5.0 \times 10^{-4}$ g a.i/ml. Ethiosulfan resulted in 96.7% kill when applied at the field rate of $5.25 \times 10^{-3}$ g a.i/ml. The subsequent dilution of Ethiosulfan decreased efficacy very fast and resulted in 53.3, 20.0, 6.7 and 3.3% larval death at the second, third, fourth and fifth lower concentrations, respectively. Square dipping study conducted on the third instar larvae for the three insecticides, Calofos 250 EC/ULV, Ethiosulfan 35% EC and Karate 5% EC showed that Calofos caused 100% mortality of larvae at $1.25 \times 10^{-3}$ g a.i/ml (twice lower rate), and 86.7% mortality at four times lower rate ($6.25 \times 10^{-4}$ g a.i/ml). Karate and Ethiosulfan caused 99.3% mortality each, but the former at eight time lower rate ($6.25 \times 10^{-5}$ g a.i/ml) and the latter at the field rate. Dilution to the second, third, fourth and fifth lower concentrations reduced the mortality of larvae to 71.7, 53.5, 32.0, and 14.4%, respectively.

It was found that the response of ABW to the field rate of endosulfan was low. On the other hand, effective control of the pest was achieved by very low concentrations of lambdacyhalothrin and profenofos ECs. In both, larval immersion and square dipping studies, the order of insecticide efficacy was karate > calofos > ethiosulfan. The low percentage kill obtained from endosulfan, ethiosulfan 35% EC confirmed the reduced efficacy of the pesticide against ABW.

Table 13. Susceptibility of African bollworm populations to synthetic insecticides in 2004.

| Insecticide | African boll worm populations and status of resistance | | | | | |
|---|---|---|---|---|---|---|
| | Arbaminch | Werer | Humera | Dubti | Dukem | Zema |
| Endosulfan | 3.452MS | 1.402S | 1.425S | 1.62S | (-)S | 1.15S |
| Profenopos | 1.249S | 1.051S | 1.044S | 2.00S | (-)S | 1.16S |
| Lamdacyhalothrin | (-)S | 3.60S | 2.68S | 10.40MS | 4.24S | 3.00S |
| Methomyl | 1.80S | 1.21S | 1.32S | 0.99S | (-)S | 1.53S |

S = susceptible, MS = moderately resistant
Source: Geremew, 2004.

Insecticide resistance in four populations of cotton aphid (Arbaminch, Dubti, Goffa and Werer) collected was studied under the laboratory and field conditions with a slide dip and pot experiments. In the slide dip test, low to moderate levels of resistance was detected for carbosulfan, furathiocarb and deltamethrin by all aphid populations tested. Similarly, the pyrethroids, deltamethrin, and lamda-cyhalotrin showed low level of efficacy both in the pot and field experiments indicating the presence of cross-resistance in cotton aphid for the pyrethroid and carbamate insecticides (Table 14). Dimethoate, endosulfan, and pirimicarb did not show any sign of resistance, although the efficacy of pirimicarb was very low (Ermias, 2006).

Table 14. Susceptibility of cotton aphid populations to synthetic insecticides in 2006.

| Insecticide | Aphid populations and status of resistance (RR Value) | | | |
|---|---|---|---|---|
| | Arbaminch | Werer | Goffa | Dubti |
| Carbosulfan 250 EC | 22.17MS | 18.67 MS | (-)S | 18.0 MS |
| Furathiocarb 200 EC/ULV | 14.08 MS | 13.50 MS | (-)S | 16.94 MS |
| Deltamethrin 2.5 EC | 17.14 MS | 12.14 MS | (-)S | 16.96 MS |
| Dimethoate 40% EC | 2.94S | (-)S | 2.36 S | 3.62 S |
| Endosulfan 35% EC | 3.65 S | 3.51 S | (-)S | 3.42 S |
| Pirimicarb 50 DP | 3.75 S | 4.41 S | (-)S | 5.08 S |

S = susceptible, MS = moderately resistant. Ermias, 2006.

## Loss assessment

Attempts to study the yield loss due to leaf miner (*Lyromiza* sp.) on cotton at Were Research Center from 1993 to 1995 was not successful due to the early occurrence of the leaf miner together with other sucking insects which made it difficult to quantify the loss incurred by the leaf miner alone. Moreover, at the time there was no systemic insecticide(s) available to control the leaf miner larvae before it incurs damage (IAR, 1996).

Loss assessment studies conducted on kenaf due to flea beetle (*Podogirca* sp.) during the 1986/87-1988/89 seasons using insecticide sprays at different plant growth stages showed that the number of leaf holes due to flea beetle attack

ranged from 4 to 6/ plant, and the treatments did not differ significantly from each other (Table 15). At harvest, perforations recorded on the top, middle and lower leaves were 10.4, 23.1, and 32.6, respectively (Table 15). This indicated that the flea beetle population at early stage of the plant was high. However, higher dry fiber yield was obtained in all of the treatment in the three seasons indicating that damage due to flea beetles had no effect on the fiber yield of kenaf (IAR, 1988). However, it was suggested that if the infestation is heavy at the seedling stage (from emergence up to 30 days) it may be necessary to apply one or two sprays to control the pest, because heavy infestations at early stages could slow down the rate of plant growth.

Table15. Mean number of holes and yield of kenaf three weeks after crop emergence and at harvest (IAR, 1988).

| **Sprayed until** | **3 weeks after emergence** | | **No. of holes on leaves at harvest** | | | **Yield (q/ha)** |
|---|---|---|---|---|---|---|
| | **No. of leaves/plant** | **No. of holes/leaf** | **Top** | **Middle** | **Lower** | |
| 84 days old | 10.7 | 4.1 | 8.8 | 26.4 | 35.6 | 70.07 |
| 70 days old | 10.9 | 5.0 | 10.9 | 20.5 | 32.9 | 69.63 |
| 56 days old | 11.6 | 4.0 | 10.5 | 22.8 | 31.9 | 68.87 |
| 42 days old | 11.0 | 4.6 | 11.0 | 23.8 | 29.2 | 70.80 |
| 28 days old | 11.2 | 5.0 | 10.0 | 23.7 | 32.9 | 70.70 |
| 14 days old | 11.7 | 4.6 | 11.3 | 22.2 | 31.1 | 66.20 |
| Unsprayed control | 11.0 | 6.1 | 10.4 | 22.3 | 34.6 | 68.33 |
| Mean | 11.2 | 4.8 | 10.4 | 23.1 | 32.6 | 69.14 |
| LSD | NS | NS | NS | NS | NS | NS |

### Control measures

In order to develop integrated pest management measures against pests of cotton in Ethiopia, different studies such as cultural control, host plant resistance, botanicals and chemicals screening experiments were conducted and results of these studies are summarized as follows.

## Cultural methods

### Plant population (spacing)

Effect of plant population on cotton leaf worm and whitefly infestations was studied at Werer and Dubti, and it was found that in the pre-spray counts higher number of cotton leaf worm larvae were recorded on widely spaced (35 and 45 cm) plants. After insecticide application, the larval population was reduced below the threshold level in all of the treatments. However, the difference in infestation between the high and low plant population levels was not significant, although the spray penetration was good in the lower plant population (IAR, 1990).

Brhane (1987) reported that high plant density of more than 62,500 plants/ha (at 70 cm spacing between rows) had increased whitefly population and relative humidity in the canopy (Table 16). The increase in whitefly population in the narrowly spaced cotton fields could be due to the creation of favorable micro-climatic conditions for the development of the pest.

Table 16. Effect of plant spacing on number of white fly adults and relative humidity at Dubti in 1984 (Brhane, 1987).

| Spacing between rows (cm) | Equivalent plant population/ha | Mean number of adults/5 leaves | Relative humidity (%) |
|---|---|---|---|
| 70 | 71,429 | 52a | 90a |
| 80 | 62,500 | 24b | 83b |
| 90 | 55,500 | 14c | 66c |
| 100 | 50,000 | 11cd | 58cd |

Means followed by the same letters are not different at 5% level (DMRT).

## Trap crops

Studies conducted on the possibility of using trap crops such as alfalfa (*Medicago sativa*), hyacinth bean (*Dolichos lablab*), maize, sorghum, pigeon pea (*Cajanus c*ajan), chickpea (*Cicer aretisimum*), okra (*Hibiscus esculentus*), groundnut (*Arachis hypogaea*), sunflower (*Helianthus annuus*) and tomato (*Lycopersicum esculentum*) for the management of the African bollworm on cotton showed that there were no significant differences among the trap crops and the main crop (cotton) in terms of egg and larvae numbers (EARO, 2002). Nevertheless, the number of eggs on hyacinth bean, okra and tomato were higher than that of chickpea; more number of larvae was recorded on pigeon pea, tomato and hyacinth bean (Table 17). In general, African bollworm egg and larva counts were higher on cotton than on the trap crops, indicating that none of the trap crops used could attract the female moth more than cotton for egg lying.

Table 17. No. of ABW eggs and larvae on trap crops and cotton at WARC in 2002/03.

| Trap crops | Average number of ABW egg and larva on | | | |
|---|---|---|---|---|
| | Trap crops | | Cotton | |
| | Egg/plant | Larva/plant | Egg/plant | Larvae/plant |
| Maize | 0.37a | 0.08a | 0.71a | 0.42a |
| Okra | 0.54a | 0.09a | 0.91a | 0.42a |
| Pigeon pea | 0.09a | 0.31a | 0.90a | 0.38a |
| Sun flower | 0.32a | 0.11a | 1.06a | 0.82a |
| Lablab | 0.55a | 0.24a | 0.99a | 0.62a |
| Tomato | 0.48a | 0.30a | 0.43a | 0.83a |
| Sorghum | 0.17a | 0.18a | 0.85a | 0.69a |
| Groundnut | 0.22a | 0.16a | 0.90a | 0.85a |
| Chickpea | 0.03a | 0.14a | 1.35a | 0.50a |
| Mean | 0.303 | 0.185 | 0.903 | 0.615 |

Means followed by the same letter within a column are not different from each other at 5% level of probability (DMRT). Source: EARO, 2002.

## Closed season

A study conducted on the effect of closed season on the population dynamics of pink bollworm in the Middle Awash area revealed that the shorter the closed season the greater the pink bollworm infestation and vise versa. The peak infestations were between September and October. Girma (1990) reported that the best way to reduce the population of the diapausing larvae was to eliminate the food supply by observing a closed season of 60-75 days.

## Host plant resistance

Cotton varieties were screened for resistance to major pests of the crop; whiteflies (Brhane, 1987; IAR, 1987; Ababu and Alemayehu, 1989); jasssids (IAR, 1987) and to the African bollworm (EARO, 2004). The immature and adult counts of whiteflies were lower on the genotypes Frego bract Del.SL, DSR, and La-okra leaf-2. However the yield performance of these genotypes was lower than the standard cultivar Acala 1517/70. On the contrary, honeydew and sooty mould were higher on the standard cultivar. The tolerant genotypes Frego Bract Del.SL, DSR, and La-okra leaf-2 have glabrous and open fingered leaves. The cultivar Albar 637 with more or less pubescent leaves was reported to be susceptibile to whiteflies. The glabrous cotton leaves were reported to disfavored egg laying and development of the immature stages. The genotypes with large canopy and dense leaves had much higher number of immatures, while the tolerant genotypes had less number of immatured whiteflies. Brhane (1987) reported that okra-leaf-2 cotton showed significantly lower number of immature stages of whitefly than AMS-1-39-1 and Acala 1517/70 (Table 18). This low number of immatures was due to the contribution of morphological features of the variety, but there was no significant difference in seedcotton

yield between the varieties. The study indicated the need for replacement of the standard cultivar with whitefly tolerant variety such as La-okra leaf-2. However, this genotype was found to be susceptible to the cotton wilt disease at Dubti.

Table 18. No. of whitefly immature/leaf and yield of three cotton varieties at Dubti in 1984 (Brhane, 1987).

| Cotton varieties | No. of immature/leaf | Yield (q/ha) |
|---|---|---|
| La-okra-leaf-2 | 4a | 24.44a |
| AMS-1-39-1 | 7b | 21.39a |
| Acala 1517/70 | 8bc | 26.11a |

Means followed by the same letter with in column are not different at 5% level (DMRT).

Cotton varieties, Albar 637, Acala SJ2, Werer-1-84, Arba, Deltapine 90, Stoneville 213, Bulk 202 and Bulk 101 were evaluated for jassid resistance at Werer from 1989-1991. The average number of jassids counted for 14 weeks showed significant differences among the varieties tested. The maximum number of jassids was recorded on Werer-1-84 and the minimum was on the standard check, Albar 637 (Table 19). Except for Werer-1-84, none of the varieties evaluated were different in yield and jassid tolerance (IAR, 1990).

Table 19. No. of jassids on released cotton varieties at Werer, 1990/91 (IAR,1996).

| Treatment | No. of jassids per 10 plants |
|---|---|
| Arbar 637 (check) | 45.70b |
| Acala SJ-2 | 54.25b |
| Werer-1-84 | 82.50a |
| Arba | 46.00b |
| Deltapine | 56.75b |
| Stonville 213 | 47.75b |
| Bulk # 202 | 59.25b |
| Bulk # 101 | 60.50b |

A number of cotton genotypes were evaluated for resistance to ABW in series of experiments conducted from 2000 to 2004. Genotypes Paymaster-145, Macnaire 235, Dunn 118, Cu-okra, G-45, Bulk 202, Bulk 101, Pima S-5, Acala 1517V and Sindos-80 had significantly low number of ABW eggs and larvae. On the other hand, genotypes Tomcot Sp-21, Carolina queen, Stonville-213, and La-frego bract-2 showed higher level of larval infestation, but the yields were also significantly high indicating that these genotypes might have the potential to compensate for damage caused by the pest. Cotton genotypes with

lower density of trichomes, higher content of gossypol glands and frego bract leaf type were found to be less attractive, unfavorable for oviposition and feeding by the African bollworm. The highest larval infestation (about 8.3 larvae per five plants) was recorded from the commercial variety Acala SJ2 that has characteristic closed bract, moderate density of trichomes and low number of gossypol gland (EARO, 2004). Ababu (1987), studied the seasonal susceptibility of the long staple cotton varieties to pink bollworm and found that the Pima-S varieties are more susceptible to pink bollworm towards the end of the crop season, when irrigation is continued and harvesting time is delayed.

# Botanical control

### Vegetable oils against cotton aphid and whitefly

Oils of canola, castor, coconut, corn, cottonseed, groundnut, safflower, soybean and sunflower each at 3% w/v were evaluated together with a synthetic insecticide carbosulfan against aphids and whiteflies in the field from 1997-1999 at Melka Werer. There were variations in efficacy against the aphids among the treatments. Vegetable oils showed 26-53% aphid population reduction, while carbosulfan caused 72% reduction. However, different oils varied in their potency, speed of action, and bio-persistence in parameters such as residual activity, spray toxicity, modification of adult's behavior expressed by settling and oviposition deterrence. Among the vegetable oils tested, groundnut, castor, and cottonseed oils showed the best performance. However, some of the oils showed phytotoxicity effect (scorching) on cotton 3-6 days after application. Coconut oil was more toxic than canola, while castor was none toxic. The order of toxicity was in the order of castor < soybean < sunflower < safflower < cotton < corn < canola < coconut. With whiteflies, conclusive results were not obtained due to the low level of infestation in the season (EARO, 2000b).

# Biological methods

### Studies on natural enemies of African bollworm eggs

African bollworm egg parasitism studies conducted from 1981 to 1986 at Werer showed that egg parasitism and predation increased as the cotton growing season progressed. The overall egg destruction by predators and parasitoids was 34, 55, 70 and 70% in June, July, August and September, respectively (IAR, 1987). Based on these results, ABW egg threshold was suggested to be changed from 50 in the whole season to 50, 60, 70 and 70% in June, July, August and September, respectively (IAR, 1987).

## Effect of sowing date on natural enemies of cotton aphid

Studies on the impacts of insect natural enemies conducted on early and late-planted cotton revealed that aphid population was low and the number of natural enemies was relatively high when cotton was planted early. On the contrary, the aphid population was high and the natural enemy populations were low on late planted cotton (Table 20).

Table 20. Effect of sowing date on aphid population, natural enemies and seed cotton yield at Werer in 1993 to 1995 (IAR, 1996).

| Pest | Early sowing | | | | Late sowing | | | |
|---|---|---|---|---|---|---|---|---|
| | **B1** | **B2** | **B3** | **Total** | **B1** | **B2** | **B3** | **Total** |
| Aphid | 326 | 411 | 114 | 851 | 427 | 401 | 312 | 1140 |
| Lady beetles | 7 | 14 | 10 | 31 | 5 | 12 | 12 | 29 |
| Lacewing | 4 | 3 | 2 | 9 | 3 | 2 | 1 | 6 |
| Spider | 5 | 10 | 11 | 26 | 2 | 4 | 4 | 10 |
| Yield (q/ha) | 39.6 | 35.9 | 41.0 | 38.8 | 10.1 | 11.1 | 8.9 | 10.4 |

B1= Natural enemies only, B2= Natural enemies + chemicals, B3 = Aphid free.

The major natural enemies recorded in cotton fields were lacewings (*Chrysopa* spp.), different species of ladybird beetles (*Coccinella* and *Chelomonas* spp.), syrphid flies and spiders. On early planted cotton, the seed cotton yields obtained from a weekly sprayed (41 q/ha) and unsprayed (39.6 q/ha) plots were not significantly different from each other (Table 20). The plots sprayed at the economic threshold level (B2) gave lower yield than the aphid free and unsprayed plots. Weekly spraying of insecticides did not control the aphid and the seed cotton yield obtained from late planted cotton was low (Table 20). Moreover, the lint quality was poor as it was contaminated with honeydew (IAR, 1996).

## Natural enemies of cotton whitefly

Surveys carried out in cotton growing areas of the country to understand the natural enemies of whiteflies showed that the parasitoid wasps *Encarsia transvena* and *Eretmocerus mundis* parasitized whiteflies (Berhane, 1987; EARO, 2000b). The most prevalent and widely distributed predator in cotton fields was the lacewing, *Chyrisoperla carnea*. Different species of ladybird beetles were recorded to be important predators of both whitefly and aphids. Hoverfly (Syrphidae*)* and unidentified species of spiders were also observed in low numbers (Berhane, 1987; EARO, 2000b). During the 1987/88 and 1998/99 seasons parasitism of whiteflies was observed early in June and July in different cotton fields. However, as chemical sprays against the African bollworm started the level of parasitism dropped drastically.

## Chemical control

A series of insecticide screening trials were conducted to control cotton pests (Tessema et. al., 1980). Cypermethrin (Cymbush), cyfloxylate (Bythroid), endosulfan (Thiodan, Thionex, and Ethiosulfan), deltamethrin (decis), Alpha-cypermethrin (Fastac), cypermethrin (Ripcord), and lambdacyhalothrin (karate) were recommended for the control of cotton bollworms (Table 21).

Table 21. Insecticides recommended for cotton pests management.

| Common name | Trade name | Target insect pests |
|---|---|---|
| Pirimiphos-methyl | Actellic 50% EC/ULV | Aphid |
| | Bostox 7.5 ULV | ABW |
| | Sybolt 2.5% ULV | Whitefly |
| Profenofos | Curacuron 250 EC/ULV | Whitefly |
| Cypermethrin | Cymbush | Bollworms |
| Cypermethrin | Ripcord 5% ULV | ABW, leaf worm, thrips |
| Deltamethrin | Decis 0.5% EC/ULV<br>0.6 ULV, 2.5% EC | ABW, leaf hopper |
| Furathiocarb | Deltanet 200 EC / ULV | Aphid |
| Alph-Cypermethrin | Fastac 7.5 % ULV | ABW |
| Lambdacyhalothrin | Karate 0.8% ULV | ABW |
| Carbosulfan | Marshal 25%ULV | Aphid |
| Bromopropyl | Neuron 500% EC | Red spider mite (RSM) |
| Monocrotophos | Nuvacron 40 SCW | RSM |
| Cypermethrin | Ripcord 5% ULV | ABW, leaf worm, thrips |
| Endosulfan | Thiodan 25% ULV, 35% EC | Bollworm |
| Endosulfan | Ethiosulfan 25% ULV | ABW |
| Dimecron | Phosphamidon | Aphid, Jassid |
| Metasystox-R | Oxydemethon Methyl | Aphid |
| Dursban | Chlorpyrifos | Leaf worm |
| Dicofol | Mitigan | RSM |
| Mitac | Amitraz | Whitefly, RSM |
| Permethrin | Talstar | Whitefly, RSM |
| Endosulfan | Thionex 25% ULV, 35 % EC | ABW |
| Polo | Diafenthiuron | Sucking insects |
| Suppuration | Methidathion | Aphid |
| Verimec/ dynamec | Abamectin | RSM |
| Gaucho | Imidacloprid | Aphid |
| Cruiser | Thiamethoxm | Sucking insects |
| Judoka | Lamdacyhalothrin | ABW |

ABW = African bollworm, RSM = Red spider mite
Source: Abdurahman, 1997; EARO, 2000b: 2001: 2002; 2004.

Pirimiphose-methyl (Actellic), phosphamidon (Dimecron), carbosulfan (Marshal), furathiocarb (Deltanate), suprathion (Methidathion) and diafenthiuron (Polo) were recommended as foliar sprays, while Gaucho (Imidacloprid) and Crusier (Thiamethoxm) as seed dressing insecticides to control the cotton aphid (Crow *et al*., 1972; Alemayehu, 1988; Ababu and Girma, 1990; Abdurahman, 1997; EARO, 2000b; 2001; 2002; 2004).

For the control of the red spider mite, oxydemethon-methyl (Metasystox-R), chlorpyrifos (Salut), amitraz (Mitac), dicofol (Mitigan), bromopropyl (Neuron) and dynamic (Vertimec) were recommended. Nurrel-D (cypermethrin + chlorpyrifos), Cybolt (flueythrinate), and Birilane (chlorfenvinphos) were also recommended for whitefly control (Crow *et al*., 1972; 1977; Brhane, 1987; Kumsa and Brhane, 1988; EARO, 2000b).

# Conclusion and recommendations

The cotton bollworms, aphids, thrips, jassids, and termites are the major pests of cotton, while flea beetles are important on kenaf and rain-fed cotton.

The predators and parasitoids such as the ladybird beetles, syrphid fly, lacewings and different species of spiders were abundant in association with aphids and whiteflies. Therefore, conserving and utilizing these natural enemies for the control of whiteflies and aphids in cotton farms should be given primary attention. Insecticide application before 30 days after crop emergence should not be practiced unless forced.

Through monitoring and population dynamics studies the peak infestation periods of bollworms, armyworms, whiteflies and aphids have been determined. The use of these indicators for the management of the pests will save time and unnecessary cost.

The pink bollworm diapauses inside the cottonseed, therefore, after harvest the cotton stalk, dropped bolls and seeds should be eliminated. Stores and sacks should be cleaned and the leftovers should be collected and burned. Late season irrigation that supports the development of susceptible bolls should also be avoided.

The optimum cumulative heat unit required for the emergence of ABW ranged from 2124.1 to 2634.9 degree-days. For the pink bollworm the range was from 1809.3 to 3551.2 degree-days. This could be used in forecasting field infestation by summing the cumulative degree-days starting from the first of January and taking 12$^{o}$C as a base temperature for cotton.

Sucking insect pests that infest cotton at early season could be managed by seed dressing with insecticides such as Gaucho 350 and Cruiser 350 FS at the rate of 350-400 g/ 100 kg of seed. Late planting of cotton must be avoided as this encourages high aphid infestation and harbor very low number of natural enemies. If infestation is severe and the economic threshold is attained, then the crop must be sprayed with Polo and carbosulfan 25% ulv at the rate of 1 and 2 l/ha, respectively.

The cotton varieties, Frego-bract, Del. SL.DSR and La okra leaf-2 were found to be tolerant to whiteflies, and Albar 637 was tolerant to jassids. These genotypes could be used as sources of resistance in cotton breeding and for planting materials in areas where the respective insects are problematic.

In areas where flea beetles are problem, seed dressing with Cruiser 315 FS at the rate of 350-400 g/ 100 kg seed just before planting is recommended.

## Gaps and challenges

- The type of pests and the degree of infestations on the same host vary from one region to another. Factors responsible for this variations have not been studied, without which effective and sustainable management could not be developed
- Losses and economic threshold levels are not determined for whitefly, jassid, thrips, termites, and flea beetles. Those established ones also need updating, for example, the currently used economic threshold level of 50 eggs/100 plants for ABW, regardless of the crop growth stage and egg parasitism levels, need revision
- Cotton protection is dependent on use of chemical pesticides and most entomological researches were dominated by screening of pesticides. Development of alternative pest control methods have not been given adequate attention
- Development of insect pest resistant varieties and use of bio-control agents remained untouched. Less emphasis was also given to studies on cultural control methods and botanicals
- Despite the indiscriminate use of pesticides in cotton farms, resistance monitoring programs have never been launched to develop resistance management strategies. The sole reliance on pesticides could lead to the development of resistance as in the case of whiteflies to Lambdacyhalothrin in Dubti and aphids to dimethoate in the Middle Awash
- Cotton received less research attention as compared to other crops as very few professionals are engaged in cotton research and the research facility is poorly developed
- Yields are very low at farmers' fields due to lack of resistant varieties, supply of inputs, and due to the knowledge gap in identifying and managing important insect pests
- The indiscriminate use of insecticides in large-scale cotton farms made cotton production a very expensive business, in addition to the threats posed to the environment

- Some of the insecticides failed to control major cotton pests like ABW, whitefly, red spider mite, jassids, thrips, and aphids is greatly challenging commercial cotton production

## Future

- Systematic survey is essential to identify and document insect and mite pests of fiber crops especially sisal and jute. As the type of pests on the same crop may vary with locations and time, the factors that contribute to these variations must be determined in order to come up with sustainable management options
- Losses should be quantified and economic threshold levels should be determined for the major insect pests of fiber crops
- Development of insect pest resistant varieties, cultural control methods, use of botanicals and bio-control agents must be given due attention
- Insecticide resistance monitoring programs should be launched and resistance management strategies should be developed
- The indiscriminate use of pesticides or repeated use of a single product throughout the season must be avoided by searching for effective, less hazardous alternative pesticides
- All cotton producers do not have the same level of understanding in the importance of crop and pesticide rotation, timely planting, weed and crop residue management, pesticide selection, dosage and application, etc. Thus, to fill the gaps in knowledge series of trainings should be given for pest scouts, farmers and development agents. Moreover, pest management strategies must be developed and implemented in a coordinated manner at all levels
- The increased cost of cotton production, lack of efficient pest control due to insecticide resistance and environmental concerns are some of the challenges that need urgent research focus

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# Review of Research on Diseases of Root and Tuber Crops in Ethiopia

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## Introduction

The major root and tuber crops in Ethiopia are enset (*Ensete ventricosum*), potato (*Solanum tuberosum*), sweet potato (*Ipomoea batatas)*, yam (*Dioscorea* spp), taro (*Colocasia esculanta*), cassava (*Manihot esculenta*) and anchote (*Coccinia abysssinica*). According to CSA (2005), the total area under root and tuber crops is estimated to be 362,888 ha. Of these, potato, taro, sweet potato and enset cover 51698, 24169, 45474 and 261547 ha, respectively. Most of these crops are grown in the densely populated areas of the country, and are the main sources of staple food for the inhabitants in the area, especially in drought years. Cassava and sweet potato are highly supportive as food and feed in dryland areas where rainfall is scarce and erratic.

Enset is the major food and income sources in the highly populated southern, central and south-western parts of Ethiopia. Had it not been to enset, the livelihood of the inhabitants would have been threatened. The high yield per unit area coupled with its ability to withstand drought makes it an ideal and strategic crop for the populace. In recent years, the crop is being introduced in other parts of the country.

The genus Ipomoea is known to be naturally pantropical and many wild species were also identified to exist in the country (Ferdu, 1999). Currently the crop is mainly produced in the southern and eastern parts of Ethiopia. It is a strategic crop safeguarding farmers when the food reserves from cereals fall back. The area of sweet potato cultivation has increased from 19000 ha to 25000 ha in the last 10 years (FAOSTAT, 2002). According to FAOSTAT (2001, 2002), 63% of the total sweet potato production in Ethiopia comes from the southern region, where it ranks second to enset in area coverage and to maize in consumption (Tamiru, 2006). Major zones of sweet potato production in the southern region are Welayita, Kembata/ Tembaro, Gamo Goffa, Sidama, Gedeo, Dawuro and Hadiya. Most of these areas are known for a high population density.

Potato is widely grown in areas with altitudes ranging from 1800-3000 masl. Potato production in Ethiopia was limited to homesteads for long periods till elite materials were introduced from the International Potato Center (CIP) with good resistance to late blight. The scale of production is increasing and the current area coverage for the crop is estimated to reach 165,000 ha. The contribution of potato in averting the problem of food shortage in the highlands of the country is well appreciated by the Ethiopian farmers.

Like others, root and tuber crops are attacked by a number of diseases. Enset is attacked by bacterial wilt and viral diseases, while potato especially the local varieties are very susceptible to late blight, and sweet potato is being threatened by viral diseases and nematodes. Results of researches conducted on diseases of some root and tuber crops for the last two decades are reviewed in this paper.

# Research findings

## Enset

### Diseases recorded

Twelve leaf, two root-rots, one bacterial wilt and nine nematode diseases were recorded on enset (Table 1). A viral disease was also recorded on enset causing yield losses ranging from 70-90% (Mesfin Tessera, pers. observation).

## Basic studies

### Enset bacterial wilt

Stewart (1956) first reported the disease to be caused by *Xanthomonas campestris* pv. *musacearum*. The typical symptoms are wilting of the heart-leaf followed by wilting of the neighboring leaves. When petioles and leaf sheaths are dissected, pockets of yellow or cream colored bacterial mass are clearly observed in the air pockets, and bacterial slime oozes out from cut vascular tissues. Once an ensete plant shows wilting symptoms, a total yield loss is common as the whole pseudo-stem rots inside. Cultivation of banana as intercrop or as a live fence is a common practice in the enset farming system. Damage of banana plants around enset with bacterial wilt is a common observation and once there was an epidemic of bacterial wilt of banana (Yirgou and Bradbury, 1968). Recent surveys conducted on enset wilt incidence in 24 different localities in 1997/98 and 1998/99 crop seasons indicated that the percentage incidence was highest at Gera and Suntu in 1997/98, while in Waka, Gera and Solemo the incidence was high in 1998/99 (Mesfin Tessera, unpublished).

Table 1. Diseases records on enset in Ethiopia.

| Common name | Scientific name | Reference |
|---|---|---|
| Leaf spot | *Phyllosticta* spp. | 68 |
| | *Piricularia* spp. | 68 |
| | *Drechslera* spp. | 68 |
| | C*ladosporium* spp. | 68 |
| | *Cephalosporium* spp. | 68 |
| | *Deightoniella* sp. | 68 |
| | *Mycosphaerella musicola* | 68 |
| | *Phoma* spp. | 76 |
| | *Selenophom*a spp. | 76 |
| | *Septoria* spp. | 76 |
| | T*hielaviops*is spp. | 76 |
| | *Cylindrocladium quinqueseplatum* | 76 |
| Root rot and Wilt | *Sclerotium rolfsi* | 68 |
| | *Fusarium oxysporum* | 76 |
| Bacterial wilt | *Xanthomonas campestris pv. musasearum* | 76 |
| Root nematodes | *Helicotylenchus* spp. | 63 |
| | *Hemicycliophora* spp. | 63 |
| | *Macroposthonia* spp. | 63 |
| | *Meloidogyne* spp. | 63 |
| | *Pratylenchus* spp. | 63 |
| | *Scutellonema* spp. | 63 |
| | *Rotylenchus* spp. | 63 |
| | *Trichodorus* spp. | 63 |
| Leaf streak nematode | *Aphelenchoides* spp. | 68 |
| Leaf streak virus (Badna virus) | | 81 |

## Morphological, biochemical, and pathogenicity characterization

Results of the morphological and biochemical characteristics are shown in Table 2. Gizachew (2000) indicated that yellowish colony color with mucoid growth was exhibited by all isolates of *X. cm.* Gram negative nature of the bacterium and its motility was quite evident for all *X. cm* isolates. Studies on the utilization of carbohydrates by *X. cm* isolates indicated that all *X. cm* isolates did not use lactose, maltose and manitol (Table 3). Pathogenicity tests with *X. cm* isolates obtained from different locations on different enset clones showed no significant variation and no clone by isolate interaction, mean incidence ranged from 95.7-100% (ARC, 2003). Twelve enset clones from Kembata and Hadiya, 89 clones from Sidama and Guraghe and 12 mixed enset collections from Kembata, Sidama, Hadiya Wolayita and Guraghe were evaluated for their resistance against *X. cm*, and enset clones from Kembata and Hadiya lacked complete resistance (immunity) against *X. cm*. Wilt incidence of 75 and 25% were observed on some enset clones (Gizachew, 2000; ARC, 2003). The results of 14 clones are presented in Appendix 1. The issue of recovery after wilting should be critically seen as this recovery may not be due

to real resistance. An enset plant that recovered after wilting may not reach maturity to give economic benefit. Wilting is an indication of lack of resistance gene against the disease and the recovery by producing a new heart-leaf might be misleading. However, this needs further investigation along the fate of new emerging heart-leaves from diseased plants. Susceptible clones like 'Astara' and Gulumo showed high percentage wilt incidence. On the other hand, enset clones like 'Serena', 'Nechewa', 'Anikefye', 'Dere' and 'Lemat' should be re-evaluated as they showed low percentage wilt incidence.

Table 2. Morphological and biochemical characteristics of *Xanthomonas campestris* isolates (after Gizachew, 2000).

| Biochemical Test | North Omo Woredas | | | Guraghe Woredas | | |
|---|---|---|---|---|---|---|
| | Mareka n = 14 | Loma N=18 | Boloso N = 4 | Chacha N = 11 | Yasana Welenew N = 11 | Gumer N = 6 |
| Gram reaction | - | - | - | - | - | - |
| Motility | + | + | + | + | + | + |
| Yellow colony on YPSA | + | + | + | + | + | + |
| Mucoid growth | + | + | + | + | + | + |
| Citrate utilization | - | - | - | - | - | - |
| Gelatin liquefaction | + | + | + | + | + | + |
| Nitrate reduction | - | - | - | - | - | - |
| Starch hydrolysis | - | - | - | - | - | - |
| Casien hydrolysis | + | + | + | + | + | + |
| Malonate utilization | + | + | + | + | + | + |
| Indole production | - | - | - | - | - | - |
| Hydrgen sulfide production | + | + | + | + | + | + |

- = negative and + = positive reactions, n = number of isolates

Table 3. Mode of utilization of carbohydrate by *X. campestris pv. musacearum* (after Gizachew, 2000).

| Source | North Omo weredas | | | Guraghe Woredas | | |
|---|---|---|---|---|---|---|
| | Mareka | Loma | Boloso | Chacha | Yasana Welenew | Gumer |
| Fructose | + | + | + | + | + | + |
| Galactose | + | + | + | + | + | + |
| Glucose | + | + | + | + | + | + |
| Glycerol | + | + | + | + | + | + |
| Mannose | + | + | + | + | + | + |
| Sucrose | + | + | + | + | + | + |
| Lactose | - | - | - | - | - | - |
| Maltose | - | - | - | - | - | - |
| Manitol | - | - | - | - | - | - |

- = negative and + = positive reactions

## Survival of Xcm in plant tissues and soil

Survival of *X. cm* in plant tissues under different conditions (infected plant sample buried in the soil below six inches, kept on laboratory bench and on soil surface) was studied and it was found out that the pathogen survived only for one month in the buried tissues, three months on the laboratory bench, and two months in plant sample kept on soil surface. The pathogen was recovered only within 12 days after sampling on YPSA amended with streptomycin (Gizachew, 2000).

## Cultural control of enset bacterial wilt

Cutting of enset leaves must be done using disinfected knives in order to avoid the transmission of wilt bacteria. The knives can be disinfected by soaking in 5% sodium hypochlorite solution or in ordinary house bleach. Burying of infested enset trees into deep pit or burning of dried wilt infected plant parts, and also disinfecting agricultural implements as mentioned above or washing and burning the tools in flame of fire can help in preventing the transmission of the pathogen.

## Enset viral disease

Enset streak virus (ESV) disease was recorded in all agro-ecologies studied in different parts of southern Ethiopia. Stunting of enset plant was severe in the highlands compared with middle and lower altitude areas. In moist agro-ecologies, ESV incidence was the highest while in the per-humid zone it was low (Mesfin Tessera, unpublished). Leaf narrowing, stunting and chlorotic leaf streaks are the typical symptoms of ESV disease. Partial purification of the virus from diseased leaves gave bacilliform DNA (BaDNA) viral particles with mean dimensions of 118-125 x 29.5-30 nm. Liberation of the viral particles was only found from leaves incubated at -70 $^{o}$C for a minimum of four weeks (Tessera et al., 1996; 1998). Comparison of yield data between healthy looking enset plants and severely stunted ones due to ESV manifested a yield reduction of 93 and 98% in Midesho and Pena cultivars, respectively. Moreover, circumference reduction of 74 and 77%, and height reduction of 73 and 64% were observed for Midesho and Pena cultivars, respectively (Table 4).

The correlation coefficients among disease severity scales and yield, circumference, and plant height were highly significant. There is a need to critically investigate the identity, ecology and characterize the ESV is an urgent issue to be addressed.

Table 4. Impact of ESV on various parameters of enset.

| Cultivars | Age | Parameters | Disease severity (at 0-5 scale) | | Reduction (%) | Correlation (r) |
|---|---|---|---|---|---|---|
| | | | 0 | 5 | | |
| Midesho-HS | 6 | Fresh Yield (kg) | 165 | 12 | 93 | - 0.97 |
| | | Circum (m) | 1.9 | 0.5 | 74 | - 0.93 |
| | | Pseud. Height (m) | 2.6 | 0.7 | 73 | - 0.92 |
| Pena-AK | 4 | Fresh Yield (kg) | 45 | 1 | 98 | - 0.98 |
| | | Circum (m) | 1.5 | 0.3 | 77 | - 0.98 |
| | | Pseud. Height (m) | 1.4 | 0.5 | 64 | - 0.91 |

Source: Mesfin Tessera,1995-98, survey data (unpublished).
Circum. = circumference, Pseud.= pseudostem.
Disease severity scale 0 = immune, and 5 = severe

# Nematode diseases of enset

## Enset black leaf streak disease

Black leaf streaks on young enset leaves cause immature death of the leaves. The causal agent of the disease is a leaf nematode initially identified as *Aphelenchoides* sp. (Quimo and Tessera, 1996), which was latter described as *A. ensete* sp. n. (Nematoda: Aphelenchoididae) (Swart et al., 2000). The nematode is reported to be widespread in all enset producing zones surveyed.

Survey of parasitic nematodes of enset in 25 sites representing seven agro-ecologies indicated that the dominant nematode species in enset roots were the lesion nematode, *Pratylenchus goodeyii* (Peregine and Bridge, 1992), followed by *P. zeae* (Table 5).

The highest number of *P. goodeyii* was recovered from enset root samples obtained from Agena (Guraghe zone) and Tocha (Dawro zone). The number of *P. goodeyii* in five grams of root samples ranged from 800-15020. These nematodes were known to cause toppling of enset plants during windy days due to severe root rotting and damage of enset roots. They possibly increase the susceptibility of enset plants to the bacterial wilt by damaging roots and, even play a role in the transmission of the wilt disease (Quimo and Tessera, 1996). Enset cultivars were found to differ in their reaction to *P. goodeyii*. Clones like Semwa, Gesa, Korkori, Adinona, Janjaro, Bukma and Misir contained high population of *P. goodeyii*, while Siskel, Yedi, Ginimbuwa and Bumbo contained the lowest. Therefore, screening enset clones against this important root pathogen under the greenhouse and field conditions is highly recommended.

Table 5. Distribution and density of plant parasitic nematodes on enset in Ethiopia.

| Site | Altitude (masl) | Nematode species and density | | | |
|---|---|---|---|---|---|
| | | *P. goodyei* | *P.zeae* | *Aphelencoides* sp. | *Meloidogyne* spp. |
| Agena | 2330 | 15020 | 5208 | 108 | 0 |
| Tocha | 2390 | 14050 | 2180 | 130 | 0 |
| Waka | 1710 | 8280 | 604 | 0 | 0 |
| Jinka | 1560 | 8170 | 2170 | 0 | 5 |
| Areka | 2011 | 7910 | 375 | 280 | 5 |
| Dedo | 2386 | 7606 | 1366 | 329 | 0 |
| Shebe | 1939 | 7538 | 393 | 1287 | 4 |
| S. Gimira | 2117 | 7329 | 531 | 253 | 4 |
| Agaro (gera) | 2065 | 6672 | 332 | 60 | 0 |
| Jimma | 2075 | 5208 | 1744 | 472 | 24 |
| Angacha | 2284 | 3921 | 212 | 45 | 208 |
| Limu | 2386 | 3913 | 258 | 173 | 367 |
| Solemo | 2538 | 3890 | 665 | 65 | 0 |
| Gunchure | 2159 | 3640 | 205 | 50 | 20 |
| Gazer | 1523 | 3545 | 70 | 85 | 45 |
| Leku | 2061 | 2595 | 268 | 100 | 33 |
| Bonga | 1840 | 1784 | 36 | 48 | 4 |
| Gerese | 2145 | 1550 | 1883 | 30 | 0 |
| Fesehagenet | 2544 | 1350 | 225 | 20 | 30 |
| Yirgalem | 1967 | 1300 | 88 | 36 | 0 |
| Hagereselam | 2797 | 1147 | 136 | 12 | 0 |
| Mizan | 1658 | 1128 | 54 | 60 | 25 |
| Aletawendo | 2248 | 1110 | 75 | 0 | 20 |
| Gedeo | 2061 | 1036 | 156 | 28 | 28 |
| Chelelektu | 1863 | 800 | 105 | 15 | 0 |

Source: Bogale et al., 2004.

# Potato

## Diseases recorded

Nine fungal, one root nematode, one bacterial and four viral diseases were recorded on potato in Ethiopia (Table 6). Early blight (*Alternaria solani*), Bacterial wilt (*Ralstonia solancearum*), late blight (*Phytophthora infestans*) and viruses were the most widely distributed potato diseases in all of the areas surveyed during 1993 and 1994 seasons (Table 7).

Bacterial wilt of potato was first recorded in 1956 on potato and eggplant in the Keffa region (Stewart, 1956). The pathogen was isolated from potato, eggplant and tomato samples obtained from Shewa, Arsi and Keffa regions (Stewart and Yirgou, 1967). Other workers also recorded the disease on potato and tomato from Ziway, Ambo, Bako and Guder areas (SPL, 1981). Bekele and Berga (1996) reported up to 63% incidences of the disease in some potato growing areas.

Table 6. Diseases recorded on potato.

| Disease name | Scientific name |
|---|---|
| Early blight | *Alternaria solani* |
| Leaf spot | *Ascochyta hotorum* |
| Dry rot | *Fusarium coeruleum* |
| Powdery mildew | *Leveillula taurica* |
| Charcoal rot | *Macrophomina phaseoli* |
| Root knot | *Meloidogyne javanica* |
| Powdery mildew | *Oidium* sp. |
| Late blight | *Phytophthora infestans* |
| Bacterial wilt | *Ralstonia solanacearum* |
| Root rot | *Rhizoctonia solani* |
| Root rot | *Sclerotium rolfsii* |
| Spindle tuber virus | - |
| Virus S, X, Y, PLRV | - |

Source: HARC (2005) and Stewart and Yirgou (1967)

Table 7. Incidence and severity of potato diseases in central Ethiopia during off seasons on irrigated and rain-fed potato crops in 1993 and 1994.

| Disease | Incidence | Severity |
|---|---|---|
| Bacterial wilt | 11.10 ± 2.50 | 32.13 ± 6.00 |
| Early blight | 11.85 ± 1.21 | 12.70 ± 2.52 |
| Late blight | 9.33 ± 1.63 | 10.00 ± 2.24 |
| Powdery mildew | 3.17 ± 1.41 | 6.25 ± 1.60 |
| Soft rot | 1.00 ± 0.64 | - |
| Viruses | 11.92 ± 2.20 | 0.0 |

Source: Potato program progress reports of 1993 and 1994

Severe late blight infection during the main season has been the major reason for shifting the production of potato from the main to the off season. The incidence of late blight in the off season is lower than that of the early blights and bacterial wilt diseases. Moreover, the occurrence of soft rot and powdery mildew was very much limited. The severity of bacterial wilt in the cool highlands such as Holetta, Debre Berhan, Selale areas was very low or absent. Studies in the 1993 off season showed that *R. solancearum* was high (50%) at Wondogenet followed by Ziway (33%), Holetta (25%) and Shashemene (23%) (HARC, 1993-94, unpublished).

Two major virus diseases of potato recorded were potato virus Y (PVY) and potato leaf role virus (PLRV). The former was more predominant on the local and the latter was on improved varieties with the incidences ranging from 6-19% and 16-32%, respectively.

# Basic studies

## Characterization of *P. infestans* populations

Studies using mitochondrial DNA haplotype analysis from 41 Ethiopian populations of *P. infestance*) showed 1a haplotype, a new population of the pathogen (Schiessendoppler et al., 2003). Studies made on metalaxy sensitivity of the isolates at the Health and Food laboratory in Vienna indicated that 75% of isolates were metalaxyl-sensitive, 10% intermediate and 15% resistant (Schiessendoppler et al., 2003). However, samples tested in the 2005/06 season at Holetta laboratory were metalaxyl-sensitive (Mesfin Tessera pers. observation. Selfing within the isolates was frequent and was 100% (Table 8). Oospore production was also higher in the tested samples under laboratory conditions. The investigation of Mesfin did not reveal the presence of the oospores under field conditions (HARC, 2005). The need to closely monitor *P. infestans* population for their resistance to this chemical is still a priority for successful production of potato since fungicides play key role to control the disease.

Table 8. Results of molecular analysis, metalaxyl resistance and oospore production of Ethiopian *P. infestans* isolates (after Schiessendoppler *et al*., 2003).

| No. of isolates | Mating type | mtDNA haplotype | Metalaxyl sensitivity (%) | | | Self fertility | Oospor production |
|---|---|---|---|---|---|---|---|
| | | | Suscep. | Intermid. | Resistant | | |
| 41 | A1 | 1a | 75 | 10 | 15 | 100 | - |
| 34 | - | - | - | | | - | 100 |

## Host range studies

All *P. infesatns* isolated from potato samples from Adet, Galessa, Holetta, Kossober, Shashemene and Wolmera were found to be pathogenic to tomato (cv. Money Maker). All isolates produced typical late blight symptom (HARC, 1985-2005). However, the degree of infection varied with the locations. The isolates from Adet and Galessa showed shorter latent period and produced bigger lesions than the rest of the isolates. In contrast, the isolate from tomato at Holetta did not infect potato. Generally, the isolates were more aggressive to the host from which they were isolated.

## Yield losses due to potato late blight

Estimates of loss of tuber yield attributed to late blight ranged from 2.7-67.1% with an average of 35.1% and 25.6% in the 1993 and 1994 seasons, respectively. The AUDPC was 293 and 1451.5 in the 1993 and 1994 seasons, respectively (Table 9).

Table 9. Late blight pressure and corresponding losses in yield of different potato cultivars at Holetta (after Bekele and Yayinu, 1996).

| Cultivar | 1993 | | 1994 | |
|---|---|---|---|---|
| | AUDPC | Yield loss (%) | AUDPC | Yield loss (%) |
| K-59 A (26) | 355.9 | 14.6 | 293.0 | 2.7 |
| CIP-378501.3 | 697.5 | 36.1 | 1109.8 | 5.9 |
| CIP-378367.4 | 378.0 | 37.8 | 1025.1 | 47.5 |
| Sissay | 611.8 | 37.6 | 1081.7 | 22.3 |
| UK-80-3 | 375.7 | 17.3 | 434.1 | 29.4 |
| AL-624 | 1451.5 | 67.1 | 1184.6 | 45.5 |
| Mean | | 35.08 | | 25.55 |

AUDPC = area under disease progress curve.

## Reactions of potato cultivars to viruses

Highly susceptible potato cultivars to PLRV were CIP 384298.56, CIP 382121 and CIP 378501.3 while those to PVY were CIP 378501.3, K-59-A, BR-113-112 and CIP 374080.5. On the other hand, potato cultivar CIP 387315.2 was found to be highly susceptible to PVS and eight other cultivars were found to be free from the above viruses by ELISA test (Table 10).

Table 10. ELISA test results (%) for symptomatic leaves of potato in 1993 main season (after Bekele and Berga, 1996).

| Clone | ELISA Positive samples (%) | | | |
|---|---|---|---|---|
| | PLRV | PVY | PVX | PVS |
| AL-624 | - | - | - | - |
| Sissay | - | - | - | - |
| CIP 378501.3 | 25.0 | 12.5 | 0.0 | 0.0 |
| CIP 378501.3 | 83.3 | 100.0 | 41.7 | 0.0 |
| CIP 384298.56 | - | - | - | - |
| CIP 387014.16 | - | - | - | - |
| CIP 382147.18 | - | - | - | |
| CIP 387346.13 | - | - | - | - |
| CIP 387028.1 | - | - | - | - |
| CIP 387346.2 | - | - | - | - |
| CIP 388367.4 | - | - | - | - |
| CIP 383120.14 | - | - | - | - |
| CIP KU-80.3 | 0.0 | 50.0 | 0.0 | 0.0 |
| Krolisa | 50.0 | 0.0 | 0.0 | 0.0 |
| K-59-A (26) | 50.0 | 62.5 | 0.0 | 0.0 |
| BR-113-112 | 0.0 | 100.0 | 50.0 | 0.0 |
| CIP 382121. | 100.0 | 50.0 | 50.0 | 0.0 |
| CIP 384321.3 | 0.0 | 75.0 | 50.0 | 0.0 |
| CIP 374080.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| CIP 374080.5 | 50.0 | 100.0 | 0.0 | 0.0 |
| CIP 384298.56 | 100.0 | 0.0 | 0.0 | 0.0 |
| CIP 384321.16 | 0.0 | 0.0 | 0.0 | 0.0 |
| CIP 387315.2 | 50.0 | 0.0 | 0.0 | 100.0 |

PLRV= potato leaf roll virus, PVY= potato virus Y, PVX= virus X, PVS= virus S

As potato is propagated by vegetative means, virus diseases could easily disseminate and accumulate in tubers causing degeneration of varieties and subsequent reduction in potato tuber yield. Potato viruses such as PLRV, PVY and PVX are the major causes for degeneration of varieties. The result of a study at Holetta using virus free seeds of six varieties produced through a rapid multiplication technique and subsequently grown for four consecutive years using seeds from the previous year indicated that the incidence of PLRV drastically increased and consequently marketable tuber yield decreased in all the varieties during the four consecutive years (Table 11). The rate of increase in incidence in varieties such as Tolcha and AL-624 was slow as compared to that of other varieties such as Awash and Menagesha. Consecutive use of tubers from the previous season as a seed source caused accumulation of viruses and could cause degeneration of seeds. After the four years of continuous cultivation of potato varieties using seeds from the previous season, 62%, 45%, 44%, and 41% yield reductions were recorded on varieties Tolcha, Genet, AL-624 and Awash, respectively. Therefore, seed sources should be periodically renewed form virus free sources for planting in virus prone areas.

Table 11. The incidence of PLRV and decline in marketable tuber yield of six potato varieties at Holetta from 1997 to 2000.

| Variety | PLRV incidence (%) | | | | Marketable tuber yield (t/ha) | | | |
|---|---|---|---|---|---|---|---|---|
| | 1997 | 1998 | 1999 | 2000 | 1997 | 1998 | 1999 | 2000 |
| Awash | 3.3 | 5.8 | 12.3 | 43.7 | 20.5 | 8.0 | 26.2 | 12.0 |
| Tolcha | 3.3 | 3.8 | 4.7 | 18.3 | 40.2 | 24.3 | 14.1 | 15.2 |
| Genet | 2.1 | 4.5 | 12.3 | 38.5 | 27.0 | 12.5 | 17.1 | 15.1 |
| Al-624 | 1.0 | 2.3 | 12.3 | 16.4 | 40.6 | 18.2 | 28.3 | 22.9 |
| Menagesha | 5.0 | 8.6 | 9.3 | 41.5 | 33.1 | 26.1 | 20.8 | 28.0 |
| Wechecha | - | 7.5 | 13.7 | 23.7 | - | 18.9 | 16.6 | 15.7 |
| Mean | 2.9 | 5.4 | 10.8 | 30.4 | 32.3 | 18.0 | 20.5 | 18.2 |

Source: HARC Potato Program progress report, 2000.

# Control measures

## Botanical control of potato late blight

Mekuria et. al. (2001, 2003) evaluated many different extracts from Ethiopia and Germany against potato late blight and reported that with the exception of the extracts derived from *Hagenia abyssinica* and *L. adoensis* no promising correlations were detected between *in vitro* and *in vivo* anti-fungal activities of all the tested botanicals (Table 12). It was reported that *H. abyssinica* extracts at the rate of 0.05, 0.125, 0.25, 0.5, 1 and 2.5% resulted in a corresponding *P. infestans* inhibition of 5, 15, 78, 96.6, 100 and 100% (Mekuria et al., 2001, 2003).

Table 12. Effects of natural products on *in vitro* mycelium growth and *in vivo* infection severity of *P. infestans.*

| **Plant extracts** | **Mean efficacy (%)** | |
|---|---|---|
| | ***in vitro*** | ***in vivo*** |
| *Artemisia afra* | 50.0 | 12.8 |
| *Lepidium sativum* | 79.9 | 27.2 |
| *Ruta chalepensis* | 38.3 | 12.2 |
| *Taverniera abyssinica* | 51.7 | 19.9 |
| *Lippia adoensis* | 35.9 | 37.9 |
| *Dorstenia sp.* | 10.2 | 8.7 |
| *Commiphora abyssinica* | 12.4 | 14.4 |
| *Hagenia abyssinica* | 100.0 | 62.2 |
| *Albizia sp.* | 52.23 | Nt |
| *S. officinalis + P. nigrum* | 82.2 | 80.0 |
| *H. abyssinica + P. nigrum* | Nt | 64.6 |

(Modified from Mekuria *et al*., 2001 and 2003).
Nt = not tested

The effectiveness of three different concentrations (0.1, 0.5 and 2.0% m/v) of *H. abyssinica* extracts in protecting tomato from late blight was compared with extracts based on a mixture of *H. abyssinica* (1.0% m/v) with either *S. officinalis* or *P. nigrum* (1:1 ratio), and a dose dependent efficacy was noted for the pure *H. abyssinica* extracts. The maximum degree of effectiveness (> 60%) against disease pressure of zoospores of late blight was attained following spraying the extract at 2% m/v. The applications of extract mixtures from *Hagenia* and *Piper* (1.0 % m/v) caused the maximum (65%) reduction of late blight infection indicating that extract mixtures may have synergetic effects (Fig. 1).

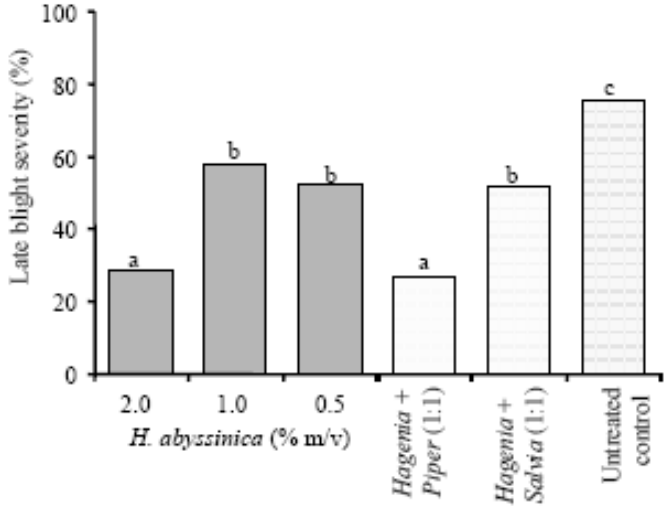


Fig.1. Effects of *H. abyssinica* extracts alone or mixed with *Piper nigrum* or Salvia officinalis on severity of *P. infestans* in the greenhouse.

## Bioagents

*Tricoderma viride* and *Pseudomonas fluorescens* were evaluated in the greenhouse at the Holetta Research Center, and found to minimize the disease severity as measured by AUDPC (Ephrem, 2005). The mixed culture of the above two organisms was not as effective as the single culture application indicating the lack of synergy.

## Host resistance to late blight

Potato varieties differ in their reaction to late blight infection. Evaluation of numerous potato clones for their resistance to late blight disease between 1990 and 1993 at Holetta showed a considerable difference among the clones in their area under disease progress curve (AUDPC) value. Clones CIP-38137615, CIP-3821215, CIP-38217312 and CIP-3873152 gave low AUDPC values as compared to the susceptible cultivars. These clones also gave significantly higher tuber yields (Table 13), however, the acceptability of the clones by farmers should be confirmed further.

Table 13. Evaluation of some potato clones to late blight in different years at Holetta (after Bekele et al, 1995).

| Potato clones | Area under disease progress curve (AUDPC) | | | 1993 yield (t/ha) |
|---|---|---|---|---|
| | 1990 | 1991 | 19931 | |
| CIP-381376.15 | 33.8cd | 0.0e | 256.7d | 28.8b |
| CIP-387346.13 | 33.8cd | 600.0b | 488.3cd | 19.2d |
| CIP-382157.30 | 150.0c | 600.0b | 753.5bc | 12.5e |
| CIP-387315.2 | 150.0c | 33.8cd | 435.4cde | 39.1.a |
| CIP-382121.5 | 150.0c | 150.0c | 268.3d | 26.5bc |
| CIP-382173.12 | 150.0c | 150.0c | 297.5d | 29.3b |
| CIP-387894.2 | 450.0bc | 33.8cd | 205.5d | 20.0d |
| CIP-387028.36 | 600.0b | 600.0b | 146.0f | 18.4d |
| Local Check | 600.0b | 435.4bc | 280.1b | 21.2cd |
| Local Check | 1150.0a | 2095.4a | 2400.0a | 15.6de |
| Mean | 355.8 | 469.8 | 553.0 | 23.1 |

## Chemical control of potato late blight

Several fungicides were tested on a susceptible potato variety (AL-624) in 1996 and 1997, and found that all of the fungicides significantly controlled late blight and increased tuber yield (Table14).

The percentages of disease control and yield increase ranged from 22-90% and 177- 485%, respectively. The disease severity on the tolerant variety (Tolcha) was significantly less than that of AL-624. The yield increase obtained through fungicide application on Tolcha was not significant compared to the susceptible

variety. This indicated that spraying the susceptible variety with one of the fungicides is economically feasible. The net benefit and the marginal rate of return were high. The two contact fungicides, chlorothalonil and Brestan 10 could be affordable to farmers for a reasonable control of late blight and good return (Table 14).

Fungicide verification experiments at Holetta and its vicinity indicated that Agro-laxyl and Mancozeb were effective on potato late blight (Table 15). Plants sprayed with qish-cozeb were less diseased than the unsprayed check. The mean analysis indicated a significant difference among the treatments in AUDPC and tuber yield (Table 15). The mean analysis of AUDPC indicated a significant difference among the treatments, although this situation was not manifested in the tuber yield, as the test fungicide (qish-cozeb) and the standard check gave comparable yields.

Table 14. Effect of fungicides on late blight disease severity and yield in 1996 and 1997 seasons (after Bekele and Hailu, 2001).

| Treatment | Tolcha | | AL-624 | | | |
|---|---|---|---|---|---|---|
| | Blight control (%) | Yield increase (%) | Blight control (%) | Yield increase (%) | Net benefit (birr) | MRR (%) |
| **1996 season** | | | | | | |
| Chlorothalonil 50% EC | 46.9 | 63.7 | 59.3 | 205.8 | 5230.0 | 248 |
| Ridomil MZ 63.5%WP | 45.4 | 61.1 | 78.8 | 369.2 | 7334.0 | 192 |
| Mancozeb 80% WP | 51.9 | 36.3 | 43.4 | 184.6 | 4650.0 | - |
| Brestan 10 | 55.6 | 50.3 | 46.8 | 176.9 | 4838.0 | 451 |
| Control | 00.0 | 00.0 | 00.00 | 00.0 | - | - |
| | | | | | | |
| **1997 season** | | | | | | |
| Chlorothalonil 50% EC | 52.9 | -15.6 | 75.5 | 355.1 | 13292.0 | 171 |
| Ridomil MZ 63.5%WP | 53.3 | -0.1 | 82.3 | 485.4 | 14890.0 | 487 |
| Mancozeb 80% WP | 31.9 | -25.0 | 57.8 | 303.0 | 1188.0 | - |
| Ridomil MZ 63.5%WP + Mancozeb 80%WP | 28.9 | -8.3 | 90.2 | 415.7 | 13505.0 | 104 |
| Brestan 10 | 68.7 | -39.1 | 22.3 | 217.2 | 5222.0 | 198 |
| Control | 00.0 | 00.0 | 00.0 | 00.0 | - | - |

MRR = marginal rate of return

Table 15. Late blight severity (AUDPC) and yield (q/ha) for different fungicide treatments at different locations.

| Treatment | AUDPC | | | | Mean yield (t/ha) |
|---|---|---|---|---|---|
| | Holetta | Erob Gebeya | Jeldu | Mean AUDPC | |
| Agro-laxyl | 875 | 182 | 107 | 388c | 1.86a |
| Qish-Cozeb | 1808 | 885 | 595 | 1096b | 12.4b |
| Mancozeb | 1185 | 471 | 301 | 652c | 12.7b |
| Control (Unsprayed) | 2540 | 2178 | 1673 | 2130a | 4.5c |
| CV% | | | | 13.5 | 21.5 |

The effects of different rates and spray intervals of Ridomil MZ 63.5% WP in protecting potato varieties with different levels of resistance to late blight were studied at Holetta, and results showed that all rates and spray intervals tested significantly increased tuber yield (Table 16).

Table 16. Main effects of rate and spray intervals of Ridomil MZ 63.5% on late blight and yield in 1993 at Holetta.

| Fungicide rate (kg/ha) | Blight Devt. (AUDPC) | Tuber Yield (t/ha) | |
|---|---|---|---|
| | | Sprayed | Unspryed |
| 0 | 836.3 | | 13.2 |
| 1 | 214.8 | 22.8 | |
| 2 | 87.5 | 27.3 | |
| 3 | 79.3 | 26.4 | |
| Spray intervals (days) | | | |
| 10 | 44.8 | 25.9 | |
| 20 | 153.5 | 25.6 | |
| 30 | 184.4 | 24.1 | |
| Varieties | | | |
| AL-624 | 403.1 | 23.9 | 7.4 |
| CIP378005.3 | 144.2 | 23.3 | 16.6 |
| UK-80-3 | 83.8 | 24.6 | 15.5 |

Source: Potato Program Progress Report for 1994.

The higher rates (2 and 3 kg/ha) reduced late blight development significantly as revealed by lower AUDPC and increased yields compared to 1kg/ha. Although the AUDPC values increased with the increase in the spray interval, the corresponding increments in yield were not significant suggesting that spraying at intervals of 10-20 days could be adequate.

Potato varieties significantly differed on the late blight disease development (AUDPC) but this was not reflected on the yield. The susceptible variety (Al-624) responded better than the two relatively resistant varieties to the higher fungicide rates and to the shorter spray intervals. The yield increase in the susceptible variety following fungicide spray was about 223%, while the increment in yield of the CIP378005.3 and UK-80-3 was only 40% and 59%, respectively.

Similar studies conducted at Holetta and Galessa in the 2000 main season using a moderately resistant (Tolcha), moderately susceptible (Menagesha) and a susceptible (Awash) varieties of potato and Dithane M-45 at 3 kg/ha sprayed at 7, 14 and 21 days interval indicated that spraying significantly reduced disease development and increased tuber yield in all varieties at both locations (Table 17).

Table 17. Main effects of varieties and spray intervals on late blight (AUDPC) and tuber yield at Holetta and Galessa in 2000.

| **Treatments** | **Holetta** | | **Galessa** | |
|---|---|---|---|---|
| | **AUDPC** | **Yield (t/ha)** | **AUDPC** | **Yield (t/ha)** |
| Variety | | | | |
| Tolcha | 282.6b | 16.5a | 629.7a | 7.9b |
| Awash | 1406.1a | 7.3c | 701.2a | 5.3c |
| Menagesha | 1391.8a | 11.5b | 503.1b | 21.3a |
| Spray Interval | | | | |
| 7 days | 529.3d | 23.1a | 395.0c | 14.1a |
| 14 days | 857.9c | 15.3b | 568.9b | 12.9ab |
| 21 days | 1128.5b | 13.3b | 665.4b | 10.8b |
| No spray | 1591.7a | 8.8c | 815.9a | 8.2c |

Spraying Dithane M-45 at 3 kg/ha at 7 days interval was the best in controlling the disease and increasing yield which is in agreement with the company's recommendation. The variety Tolcha has tolerated the disease and yielded high at Holetta but not at Galessa. There were significant interactions between varieties and spray intervals. The increase in tuber yields of Menagesha and Awash was 1105% and 280% following spraying at 7 days interval at Holetta, while the increment with Tolcha was only 54%.

# Integrated late blight management

## Varieties, plant population and fertilizer

The effects of plant density and fertilizer on late blight disease severity and yield of two potato varieties were investigated in the 1997, 1999 and 2000 main seasons at Holetta. The effects of variety, plant density and fertilizer levels on late blight disease severity and tuber yield were generally variable in the three seasons (Table 18).

Table 18. Effect of variety, plant density and fertilizer on late blight severity and yield of potato at Holetta.

| Treatments | 1997 | | | 1999 | | | 2000 | | |
|---|---|---|---|---|---|---|---|---|---|
| | AUDPC | Lesion No. | Yield (t/ha) | AUDPC | Lesion No. | Yield (t/ha) | AUDPC | Lesion No. | Yield (t/ha) |
| Varieties | | | | | | | | | |
| AL-624 | 196.7 | 17.5 | 22.1 | - | - | - | - | - | - |
| Awash | 288.2 | 21.1 | 19.9 | 892.6 | 18.7 | 6.4 | 315.4 | 19.4 | 12.1 |
| Menagesha | - | - | - | 704.5 | 21.1 | 8.7 | 624.8 | 15.4 | 18.5 |
| Plant density/ha | | | | | | | | | |
| 33333 | 192.0 | 18.9 | 17.3 | 874.8 | 18.0 | 5.9 | 446.5 | 16.6 | 12.8 |
| 44444 | 212.0 | 18.3 | 19.7 | 734.5 | 15.1 | 9.3 | 494.0 | 17.6 | 14.6 |
| 83333 | 323.3 | 20.6 | 25.6 | 815.9 | 26.7 | 7.2 | 468.5 | 18.0 | 18.6 |
| Fertilizer rate/ha | | | | | | | | | |
| P2O5 111N+89.7 | 249.9 | 18.7 | 24.9 | 1003.7 | 19.8 | 8.8 | 511.2 | 17.0 | 16.3 |
| P2O5 54N + 138 | 337.4 | 17.5 | 22.8 | 760.1 | 18.3 | 10.0 | 495.1 | 17.8 | 15.6 |
| P2O5 23 + N 9 | 140.1 | 21.7 | 15.3 | 686.9 | 21.9 | 3.8 | 403.9 | 17.5 | 14.0 |

Increasing plant populations increased yield in all seasons, despite the significant increase in disease severity in 1997. Although values of AUDPC increased at higher fertilizer levels, tuber yield also increased probabily due to improved soil fertility and increased plant population. The development and progress of the disease was found to be generally influenced to some extent by the interaction of the three factors tested.

## Varieties, planting date and fungicide application

The effect of varieties and planting dates on severity of late blight disease and potato yield was investigated for three seasons under fungicide protected (Ridomil MZ 63.5% WP at 2.5 kg/ha) and unprotected plots at Holetta. The varieties used were Tolcha, Awash and AL-624 and planting dates were early June (3-7), mid June (18-21), early July (3-5) and mid July (18-19). It was observed that the disease appeared 22-27, 29-35 and 39-43 days after planting on AL-624, Awash and Tolcha, respectively (Table 19).

Table 19. Effect of variety, planting date and fungicide application on severity of late blight and potato tuber yield (after Bekele and G/Medhin, 2000).

| Treatment | 1993 | | | 1994 | | | 1996 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Disease onset (days) | AUDPC | Yield (t/ha) | Disease onset (days | AUDPC | Yield (t/ha) | Disease onset (days) | AUDPC | Yield t/ha |
| Variety | | | | | | | | | |
| AL-624 | 27bc | 821.5a | 8.7c | 24b | 750.8a | 4.6b | 22b | 1351.4a | 5.6c |
| Awash | 32ab | 291.9b | 16.6b | 35ab | 615.4a | 7.1b | 29ab | 1181.5ab | 11.3b |
| Tolcha | 41a | 142.0b | 23.4a | 43a | 462.8a | 11.7a | 39a | 466.6c | 21.6a |
| Planting date | | | | | | | | | |
| Early June | 42ab | 652.8a | 25.7a | 38a | 867.4a | 13.4a | 40a | 1567.0a | 20.1a |
| Late June | 45a | 570.0ab | 23.0ab | 35ab | 637.5ab | 6.1b | 29ab | 1260.0ab | 16.2b |
| Early July | 27c | 298.2b | 9.2c | 26abc | 447.3bc | 5.5b | 23bc | 896.4c | 8.4c |
| Late July | 28c | 251.0c | 7.2c | 21bc | 486.6bc | 6.3b | 19c | 276.1d | 6.8c |
| Fungicide | | | | | | | | | |
| No | - | 416.1 | 16.3 | - | 499.0 | 7.8 | - | 998.8 | 12.8 |
| Yes | - | 14.1 | 23.0 | - | 55.2 | 12.5 | - | 182.9 | 23.6 |

Disease onset = number of days from planting to the first late plant appearance

Similarly, disease development was faster on the susceptible variety (AL-624) as indicated by the higher AUDPC. Although early planting resulted in significantly higher AUDPC, the disease onset was significantly delayed and consequently, tuber yield was significantly higher over the three years. There was no clear evidence of the interaction between varieties and planting dates. Early planting of tolerant varieties gave reasonable yield, though late blight development was higher. Spraying Ridomil has significantly reduced disease severity and increased yield in all the varieties and sowing dates. There were significant interactions between the fungicide treatment, varieties and planting dates (data not presented). The yield increase brought about by fungicide spraying on AL-624 (susceptible variety) was much higher at the early than late planting, whereas spraying early planted Tolcha (tolerant) did not increase yield. Therefore, susceptible varieties can be planted early by protecting them with fungicides. On the other hand, tolerant varieties such as Tolcha can be planted early without fungicide application (Bekele and Gebremedhin, 2000).

## Economics of integrated management of late blight

Studies on the economic advantage (as indicated by the partial budget analysis) of integrating variety, planting date and fungicide spray revealed that variety Menagesha provided the highest net benefit followed by Tolcha and Awash.

Farmers could get 2081 and 1023% marginal rate of return from integrated use of the three management options (Table 20).

If farmers do not access fungicides and/or missed early planting, Tolcha should be used as it was better than Menagesha in terms of disease resistance, net benefit and marginal rate of return. In general, improved potato varieties integrated with both or one of the management components could improve the production of potato as opposed to the local variety.

Table 20. Economics of integrated management of late blight (Bekele and Hailu, 2001).

| Management Options | Variety | Yield (t/ha) | Net benefit (birr) | MRR (%) |
|---|---|---|---|---|
| Variety + early planting fungicide | Local | 32.4 | 22528 | 477 |
| | Awash | 18.3 | 25479 | |
| | Tolcha | 28.0 | 40502 | 1023 |
| | Menagesha | 31.4 | 46017 | 2081 |
| Variety + early planting | Local | 3.6 | 41.6 | |
| | Awash | 6.4 | 6062 | 483.0 |
| | Tolcha | 25.3 | 36362 | 1666 |
| | Menagesha | 10.3 | 10597 | |
| Variety + fungicide | Local | 30.6 | 25140 | |
| | Awash | 18.1 | 20998 | 670 |
| | Tolcha | 28.7 | 39652 | 988 |
| | Menagesha | 27.5 | 41427 | 670 |

MRR = marginal rate of return

Studies conducted in Jeldu, Galessa and Welmera Weredas on integrated management of late blight disease through farmers field school approach (FFS) showed that the majority of farmers appreciated working in groups; were able to recognize the symptoms of late blight on the foliage and tuber; know the cause and life cycle of the pathogen, understand proper handling and application of fungicides; identify superior varieties based on their resistance to late blight (Bekele *et a*l., 2002).

## Potato bacterial wilt management

Integrated management of bacterial wilt through the use of improved varieties, healthy and clean seeds, fertilizer at the recommended rate during planting, rouging of diseased plants, using uninfested fields, earthling, etc. were compared with farmers' practices (local variety and traditional practices) in the 1999 and 2000 seasons. The improved practices gave significantly effective control of bacterial wilt in both seasons. Bacterial wilt incidence in the improved practices ranged from 0.2-5.6% while it was 10.8-21.6% under the farmers practice (HARC, 2000). However, the amount of rotten tubers were

higher (16.7-55.5%) and marketable yields were lower (15.8-17.8 t/ha) in the improved practice than in the other treatment (farmers practice) (18-23.4% and 18.6-21.3 t/ha) (HARC, 2000). This observation requires further confirmation.

The effect of preceding crop on potato wilt disease was studied using two potato varieties at the Ambo Plant Protection Research Center in 1996-1997. The result showed that wilt incidence was significantly ($p<0.05$) influenced by the type of the preceding crop (Table 21).

Table 21. Effects of preceding crop and post emergence cultivation on bacterial wilt incidence and yield of potato (after Bekele and Berga, 2001).

| Preceding crop | Awash (Tolerant Variety) | | | | | |
|---|---|---|---|---|---|---|
| | One Time Hilling | | | Two Time Hilling | | |
| | Incidence (%) | Rotten Tubers in DLS (%) | Yield t/ha | Incidence (%) | Rotten Tubers in DLS (%) | Yield t/ha |
| Wheat | 0.0 | 24.9 | 24.3 | 0.0 | 3.6 | 31.67 |
| Beans | 0.0 | 8.9 | 31.6 | 0.0 | 7,.1 | 31.33 |
| CIP-384321.3 | 0.0 | 15.4 | 30.3 | 0.0 | 20.5 | 35.67 |
| Awash | 0.0 | 3.7 | 31.0 | 0.0 | 3.2 | 32.00 |
| Maize | 0.0 | 9.0 | 34.0 | 0.0 | 7.1 | 32.67 |
| | CIP-384321.3 (Susceptible Variety) | | | | | |
| Wheat | 7.2 | 6.1 | 31.6 | 9.4 | 7.3 | 34.00 |
| Beans | 31.0 | 3.5 | 31.3 | 29.9 | 1.7 | 29.33 |
| CIP-384321.3 | 18.8 | 4.1 | 35.6 | 31.9 | 1.2 | 24.33 |
| Awash | 40.9 | 1.9 | 32.0 | 42.9 | 1.8 | 25.33 |
| Maize | 14.1 | 3.6 | 32.6 | 4.5 | 0.0 | 44.33 |

The incidence of wilt on the susceptible variety was 23.0% while that of the tolerant variety was 0%. The percentage of tuber rot at harvest differed significantly ($P<0.05$) with the variety, but not with the type of the preceding crops and hilling. The percentage of tuber rot after three weeks of storage in diffuse light store (DLS) was significantly ($P<0.05$) affected by the type of the preceding crops and potato varieties. Marketable tuber yield of potato planted after maize was significantly ($P<0.05$) higher than that of the other crops. Tuber yield also significantly ($P<0.05$) varied with potato varieties and hilling treatments. The correlation between tuber yield and wilt incidence was negative and significant ($r = -0.86$). The use of maize or wheat as a preceding crop and tolerant potato varieties are important components for the management of potato bacterial wilt.

# Sweet potato

## Diseases recorded

Four fungal, one bacterial and two viral diseases were recorded on sweet potato (Table 22). Tamiru (2006) reported an outbreak of a sweet potato virus like disease.

Table 22. List of sweet potato diseases recorded in Ethiopia.

| Disease Name | Scientific Name | Ref. |
|---|---|---|
| Sweet Potato FMV | Potyvirus | 71 |
| Sweet potato virus G | Potyvirus | 71 |
| Leaf spot | *Xanthomonas vesicatoria* | 37 |
| Leaf blight | *Ascochyta hortorum* | 76 |
| Stem blight | *Alternaria sp.* | 37 |
| Stem blight | *Colletotricum* sp. (*glomerella singulata*) | 37 |
| Leaf rust | *Puccinia holosericea* | 76 |

FMV = Feathery Mottle Virus

## Basic studies

According to Hahn et al. (1981), SPFMV isolates from Ethiopia had very restricted host ranges. Mechanical inoculation to herbaceous plants did not lead to infections, particularly repeated attempts to transmit the isolates to *Chenopdium quinoa* and *Nicotiana benthamiana* were not successful. Mechanical and graft inoculation in *Ipomoea nil*, *I. setosa* and *I. purpurea* showed symptoms of vein clearing, leaf distortion, yellowing and chlorotic spots. One isolate (ark21) produced latent infection in *I. purpure*a (Tamiru, 2004 and 2006). Isolates reacted differently to different sera. DAS-ELISA reactions of selected isolates subjected to different SPFMV antisera are presented in Table 23.

Table 23. DAS-ELISA detection of selected SPFMV isolates from Ethiopia.

| Isolates | SPFMV Antisera | | | | | |
|---|---|---|---|---|---|---|
| | C | 1C4a | 46b | CIP | AS-0530 | AS-0531 |
| Ark21 | 0.735b(++c) | 2.052 (+++) | 0.752 (++) | 0.561 (++) | 0.230(+) | 0.432 (+) |
| Bod24 | 0.682(++) | 2.069 (+++) | 0.079 (-) | 0.401 (+) | 0.215(+) | 0.412 (+) |
| humb1 | 0.402 (+) | 1.210 (++) | 0.375(+) | 1.274 (++) | 0.760(++) | 0.871(++) |
| Sodo19 | 0.345 (+) | 1.995 (+++) | 0.630(++) | 1.211(++) | 0.643(++) | 0.792(++) |
| Bod17 | 0.310 (+) | 2.224 (+++) | 0.448(+) | 0.610(++) | 0.312(+) | 0.452(+) |
| Aw18 | 1.180 (++) | 0.283 (+) | 0.066 (-) | 0.581(++) | 0.384(+) | 0.526(++) |
| bolo23 | 0.107(+) | 0.102 (+) | 0.030(-) | 0.210(+) | 0.275(+) | 0.321(+) |

a Monoclonal antibody , b values of mean absorbance of two readings. c +++ = x $\geq$ 1.5, ++ = 0.5 $\leq$ x < 1.5, + = 0.1 $\leq$ x < 0.5 and = x< 0.1, where x indicate the absorbance value.

Variability in the detection limit could be observed between the different antisera. The monoclonal antibody 1C4 reacted very strongly with most isolates. The Mab showed less sensitivity to isolates aw18 and bolo32. The polyclonal antiserum against SPFMV-C detected isolate ark21, bod24 and aw18 better than humb1 and sod19 (Tamiru, 2004). In addition, it reacted weakly to the isolate bolo23. Detection capacity of other polyclonal antisera also varied.

In molecular studies the coat protein (CP) genes including the untranslated regions (3' UTR) of two SPFMV isolates were determined. In addition, the 3' UTR of two other isolates was sequenced. A BLAST search in the gene bank for similarity of sequences gave highest scores with sequences of SPFMV isolates from other countries (Tamiru, 2006 and Table 24).

Table 24. Virus isolates used in sequence comparison with the Ethiopian isolates.

| **Virus / isolate** | **Origin of isolate** | **Accession number** |
|---|---|---|
| SPFMV-Mad | Madagascar | AJO10700 |
| SPFMV-Nam1 | Uganda | AJO10704 |
| SPFMV-RC | USA | S43450 |
| SPFMV-C | USA | S43451 |
| SPFMV-K1 | Korea | AFO15540 |
| SPFMV-S | Japan | D38543 |
| SPFMV-6 | Argentina | U96625 |
| SPFMV-O | Japan | D16664 |
| SPFMV-Z | Zimbabwe | AFO16366 |
| SPVII | Nigeria | AY232437 |
| SwPLV | China | X84011 |
| SPMSV | Argentina | U61228 |
| SPVG-CH | China | X76744 |
| SPVG-Egyp | Egypt | AJ515380 |
| PVYN | North America | AY166867 |

Comparison of nucleotides and the deduced amino acids sequences of the CP gene revealed clear differences between the two Ethiopian isolates (Tamiru, 2004). In the coat protein gene, the two Ethiopian isolates shared 73 and 82.5% nucleotide and amino acid sequence identities, respectively. Considerably high nucleotide (93%) and amino acid (aa) sequence (94%) similarities were found between the ark1 and SPFMV-C strain. SPFMV-ark1 shared 75 and 83% identity with SPFMV-RC strain at nucleotide (nt) and amino acid sequence levels, respectively. In the contrary, humb1 had aa sequence identities of 96.5% with SPFMV-RC strain and 83.4% with SPFMV-C strain. The highest identity (98.1%) was observed between humb1 and Nam1 (Ugandan isolate).

Phylogenetic analysis at nucleotide (Fig. 2) and amino acid sequence levels (Fig. 3) clustered ark1**,** SPFMV-C and SPFMV6. The analysis assigned humb1 to the SPFMV-RC strain and added all other compared SPFMV isolates to this group. For alignment of sequences and phylogenetic analysis of the 3' UTR (Fig. 4), two more Ethiopian SPFMV isolates were included. Alignments of the 3' UTR nucleotide sequences and further phylogenetic analysis confidently supported the observed differences in the coat protein nucleotide and amino acid sequences. The analysis with the 3' UTR nucleotide sequences evidently clustered the four Ethiopian isolates into two different groups (Tamiru, 2004). Nucleotide similarities in the 3'UTR within the four Ethiopian isolates ranged between 81-98%. SPFMV-humb1 and sod19 shared nucleotide sequence identities of 98%. Isolates ark21 and bod24 had 98.6% nucleotide identities. Isolates ark21 and bod24 differed from humb1 and sodo19 by only sharing similarities ranging from 81-83%.

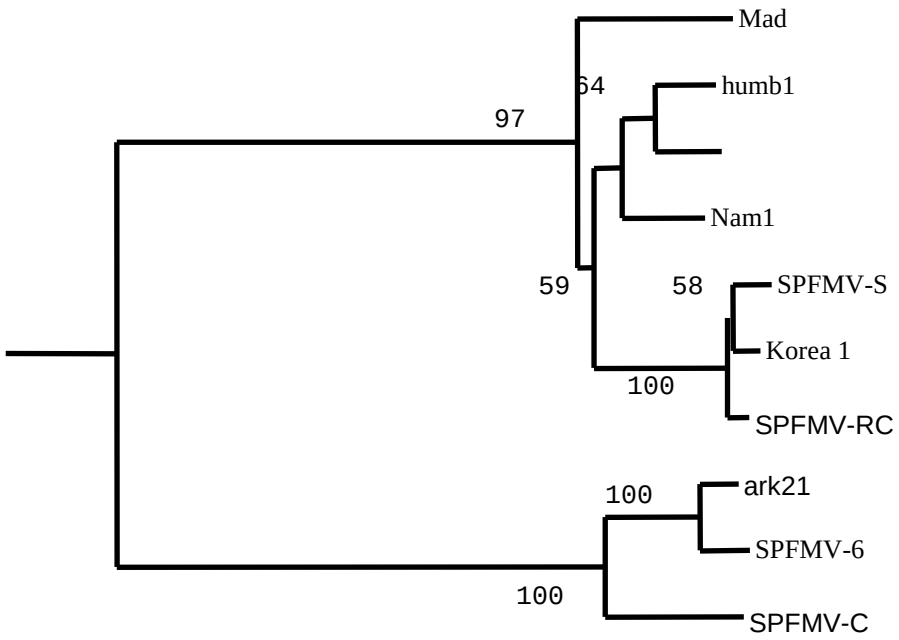


**Fig 2**. Neighbor-joining dendrogram of coat protein nucleotide sequences of SPFMV isolates. Vertical and horizontal branch lengths are arbitrary and proportional to sequence differences respectively. The number at each node indicates bootstrap scores.

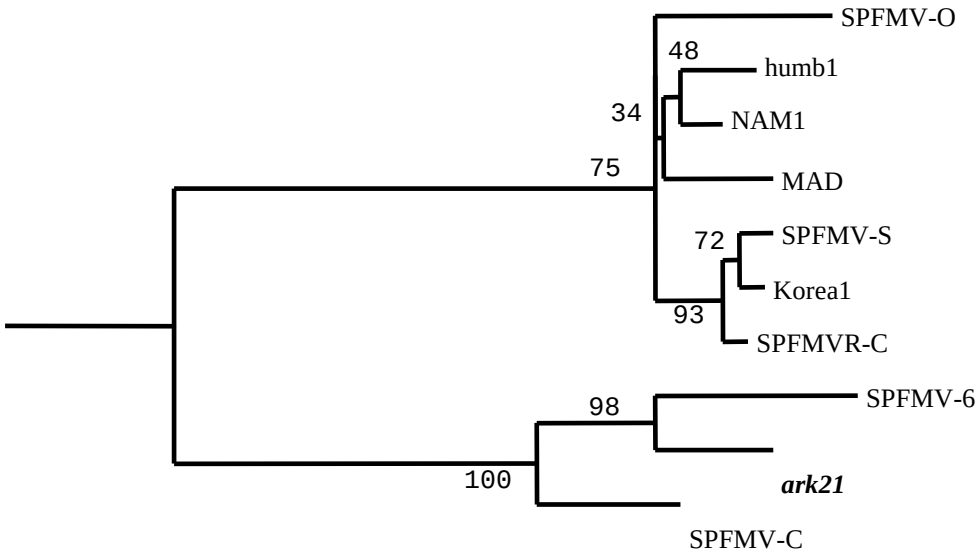


Fig.3. Neighbour-joining dendrogram of coat protein amino acid sequences of SPFMV isolates. Vertical and horizontal branch lengths are arbitrary and proportional to sequence differences respectively. The number at each node indicates bootstrap scores.

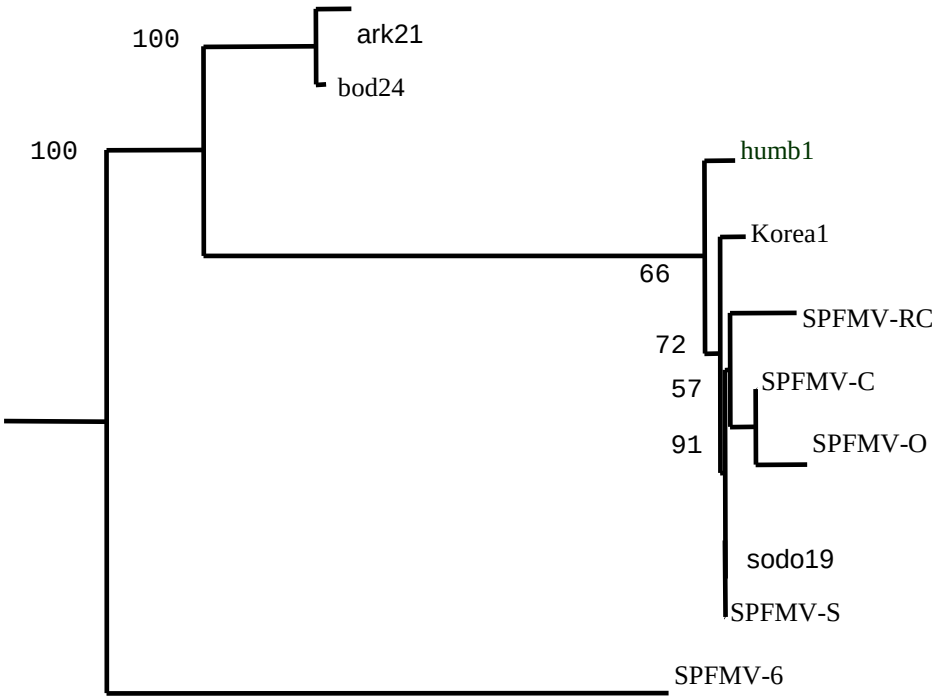


Fig. 4. Phylogenetic relationship of 3' UTR nucleotide sequences of SPFMV isolates. Vertical and horizontal branch lengths are arbitrary and proportional to sequence differences respectively. The number at each node indicates bootstrap scores.

Moreover, the CP genes including the 3' UTR regions of two Ethiopian SPVG (Fig. 5) isolates (ark15 and sodo20) were sequenced, and the deduced coat protein amino acid and 3'UTR nucleotide sequences were compared with other isolates of SPVG and potyviruses infecting sweet potato (Tamiru, 2004). The two Ethiopian SPVG isolates shared amino acid sequence similarity of 96.1%. The isolates ark15 and sodo20 had sequence similarity of 96.3% and 98.9% with the SPVG isolate from Egypt, respectively. Sequence identities of 92.4% and 94.4% were identified between the Chinese isolate and ark15 and sodo20, respectively. Overall variability in amino acid sequence identity between SPVG Ethiopian isolates and the other potyviruses infecting sweet potato ranged from 56% for *s*weet potato mild speckling virus (SPMSV) to 75% for sweet potato virus II (SPVII).

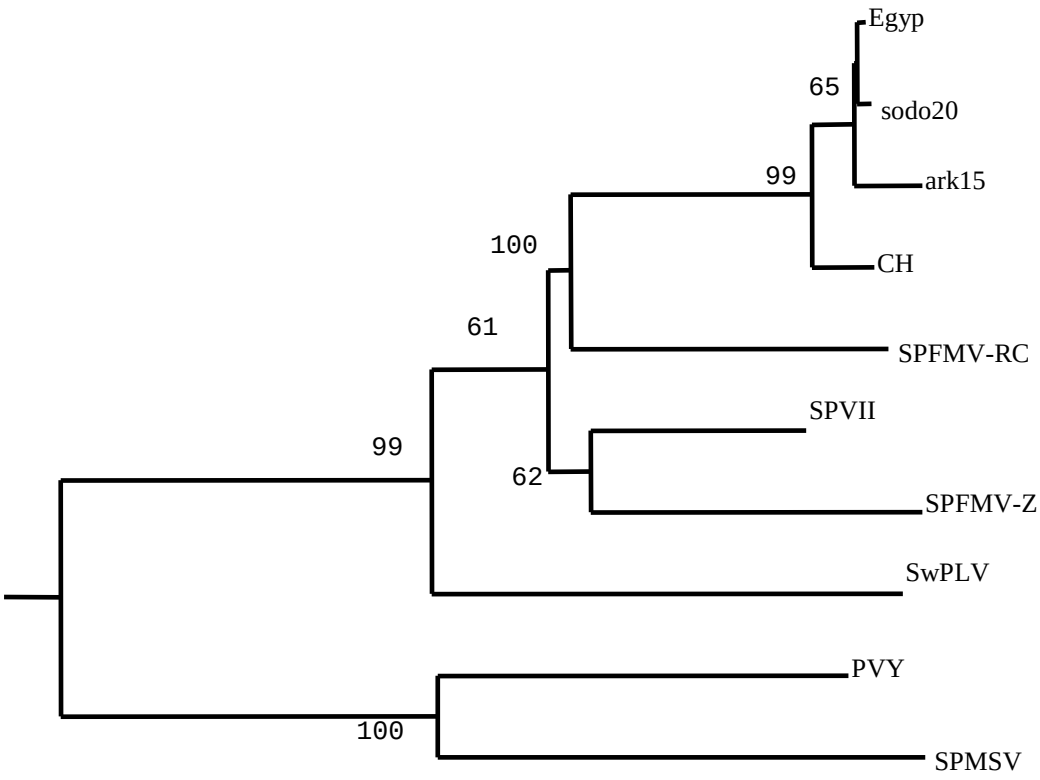


Fig. 5. Phylogenetic analysis of the coat protein deduced amino acid sequences of SPVG isolates from Ethiopia and other potyviruses infecting sweet potato. PVY was used as out-group potyvirus. Bootstrap percentages are indicated at branch points.

## Other root crops

Diseases recorded on yam and cassava are listed in Table 25. Yam diseases consisting two fungal, three root nematodes and one viral disease are listed in the disease herbarium collection at HARC. There are no threatening diseases recorded to date on yam. On taro, two fungal diseases *Cladosporium* and *Phytophthora* sp. are the only records found at HARC herbarium collection lists (Stewart and Yirgou, 1967). Diseases recorded on cassava include four fungal pathogens causing leaf spots and tuber rot. Since cassava is not widely grown in the country, limited diseases are recorded to date (Table 25).

Table 25. Diseases recorded on yam and cassava in Ethiopia.

| Disease name | Causal agent | Crop | References |
|---|---|---|---|
| Leaf spot | *Cercospora contraria* | yam | 37 |
| Leaf rust | *Rust* | yam | 75 |
| Leaf yellowing | *Virus* | yam | 37 |
| Root Nematode | *Pratylenchus sp.* | yam | 63 |
| Root Nematode | *Helicotylenchus sp.* | yam | 63 |
| Root Nematode | *Tylenchus sp.* | yam | 63 |
| Tuber rot | *Rhizopus sp.* | Cassava | 37 |
| Leaf spot | *Cercospora henningsii* | Cassava | 76 |
| Leaf spot | *Glomerella cingulata* | Cassava | 37 |
| Leaf spot | *Phomopsis manihotis* | Cassava | 37 |

# Conclusion and recommendations

Studies on the distribution of enset bacterial wilt disease revealed the importance of field sanitation. Hence, the need to reach remote enset areas with such advice is an urgent issue. In this regard, total removal of wilting plants from enset farms is a must. After cutting the petioles, rouging of the pseudo-stem must be done in a very careful manner. Roots of the wilting plant must be totally removed from the ground, the pseudo-stem well chopped and buried in a deep pit. Livestock should not be fed on the diseased plant parts.

The population of the lesion nematode recorded in huge numbers under each enset plant indicates the need for due attention as severe root damage could contribute to easy toppling, and the role of the nematodes as disease vector might further complicate the problem. Planting of enset seedlings must be done after checking the corm status for the presence of blackened discoloration, and remove it if present. It is also advisable to add some composted cowdung around the enset corm as it encourages the development of antagonistic organisms against the lesion nematode.

The impact of enset leaf streak disease was very immense on yield, height and circumference of the pseudo-stem. Hence, use of healthy planting material is advised.

The black leaf streak disease of enset seedlings caused by the enset leaf nematode requires immediate attention as is could result in shortage of planting materials. The lower part of the enset leaves touching the ground should be removed carefully from the suckers in order to avoid the movement of the leaf nematodes from the soil level to the enset leaf parts. Daily check-up of the emergence of suckers is a prerequisite for such activity.

Agro-laxyl and Qish-Cozeb fungicides at the recommended rate can be used in the control of potato late blight along with rotation with Ridomil and Mancozeb.

# Gaps and challenges

## Enset

Isolate collection for *Xcm* must be done by agro-ecology zones as difference among Sidamo, Wolayita and Hadiya isolates were detected by molecular techniques.

Screening experiments against *Xcm* must be seen with caution as susceptible clones showed low of percentage wilt incidence, high coefficient of variation, and inconsistent data on the same enset clone under different experiments (this raises the issue on non-uniformity of *X. cm* inocula) and enset plants in the control showed wilt incidence.

## Potato

Since there is high heterogenicity in the populations of *P. infestans* in the country, evaluation of clones under natural inoculum pressure should be supported with artificial exposure of clones to all isolates collected from different potato growing areas.

The results obtained from biological control studies against potato late blight under controlled conditions should be verified under field conditions before their recommendation for use in the real world.

It was observed that improved potato varieties were more susceptible to potato bacterial wilt than the local variety calling for more attention in variety development to incorporate bacterial wilt resistance in varieties for diseases infested areas.

Synthetic fungicides are the main or the sole means of controlling potato late blight, hence, search for effective, less harmful and less costly fungicides should continue.

## Sweet potato

Studies on yield losses, distribution of the viral diseases and control options are lacking. Sweet potato virus G (SPVG) is one of the incompletely characterised sweet potato viruses and data on SPVG isolates from other countries are lacking and comparisons are not possible.

## Yam, taro and cassava

These crops are not given proper research attention in many aspects including their disease and disease management.

## Directions

Research regarding bacterial wilt of enset must give attention to sanitation along site based eradication campaigns during the off seasons.

If internal quarantine is not practised for bacterial wilt of potato, the dissemination of the bacteria to uninfested areas will increase. Especially seed distribution from infested locations must be avoided. Seed certification, therefore, comes in the forefront in regard to seed distribution. The increasing incidence of viral symptoms on sweet potato plantation raises the need to monitor the disease and avoid the transportation of infected planting materials to uninfested areas. Along this line, the need to monitor the stem blight disease should not be ignored.

Research must give due attention to yam, taro and cassava as they play a crucial role in the food security of the country especially in areas where population density is high and drought is a problem.

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Appendix 1. Percentage wilt incidence on enset clones (advanced material from Hadiya and Kembata collections) under artificial inoculation.

| Clone name | Disease evaluation days after inoculation (DAI) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 21 | 30 | 45 | 60 | 75 | 90 | 120 | 150 | 180 |
| Hiniba | 8.25ab | 37.5abc | 50bcd | 50ab | 54.25abc | 58.50a | 33.5bcd | 33.5bcd | 29.26cde |
| Fugatessa | 0b | 16.75cd | 56.25abc | 46ab | 54abc | 54.25ab | 50ab | 37.75bcd | 46abcd |
| Hiella | 0b | 4.25d | 29de | 33.25bc | 29.25cde | 20.75cd | 16.75d | 21cd | 16.75e |
| Abate | 0b | 16.75cd | 21e | 16.75c | 20.75de | 20.75cd | 20.75cd | 25cd | 25de |
| Arkiya | 0b | 17cd | 21e | 17c | 17e | 17d | 17d | 17d | 17e |
| Kassiet | 12.5ab | 54a | 72.75a | 70.75a | 62.25a | 58.25a | 58.25ab | 58.25ab | 58.25ab |
| Abate merziya | 4.25ab | 37.25abc | 41.5bcde | 58.25ab | 58.25ab | 66.5a | 66.5a | 66.5a | 62.5a |
| Kembato | 14.25ab | 26.5bc | 34cde | 34.25bc | 34.25bcde | 54ab | 54ab | 45.5abc | 54abc |
| Meziya | 10ab | 22.25cd | 34cde | 38.25bc | 34.25bcde | 21.75cd | 21.75cd | 26.75cd | 22.5de |
| Gishera | 0b | 33abc | 54.25abc | 54.25ab | 54.25abc | 54.25ab | 46abc | 46abc | 46abcd |
| Astara | 10.5ab | 29.25bc | 50bcd | 58.25ab | 58.25ab | 58.25a | 55.75ab | 55.75ab | 55.75ab |
| Sokide | 18.75a | 46ab | 43.5bcde | 46ab | 46abcd | 43.5abc | 43.5abc | 43.5abcd | 43.5abcd |
| Sorpie | 8.25ab | 34.25abc | 52abc | 34bc | 37.5abcde | 25cd | 21cd | 21cd | 21de |
| Sigasurum | 21a | 54a | 62ab | 54ab | 54.25abc | 33.25bcd | 33.25bcd | 33.25bcd | 33.25bcde |
| CV | 162.44 | 48.78 | 35.57 | 40.25 | 40.73 | 40.79 | 47.35 | 49.62 | 47.58 |
| LSD 5% | 17.88 | 21.47 | 22.6 | 25.12 | 25.57 | 24.42 | 26.03 | 26.91 | 25.80 |

Source: Awassa Research Center, 2003. Plant Pathology Progress Report for 2000-2003.

# Review of Vegetable Diseases Research in Ethiopia

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## Introduction

Vegetables are important high value commodities grown in many parts of Ethiopia. These crops are important food supplements and also serve as regular sources of income for the rural poor farmers (Lemma et al., 1994). According to CSA (2003), vegetables cover 86,039 ha (1.1%) of the agricultural land. Different types of vegetables are grown around the Central Rift Valley and to some extent in urban and pre-urban areas. The major vegetables cultivated throughout the year by small and large-scale commercial farms include tomato, onion, pepper, cabbage and snap beans (Lemma et al., 1994). Other vegetables like shallot, garlic, carrot, eggplant, lettuce, Ethiopian kale, Swiss chard are also grown in small and large scales especially in urban and pre-urban areas.

However, the productivity of vegetable crops is very low due to several biotic and abiotic factors among which diseases are the major ones (Tesfaye and Habtu, 1985; Mohammed et al., 2006). The major vegetable diseases are caused by fungi, nematodes and viruses; although some of these pathogens have been identified correctly, the majority have either not been identified or named only based on the symptoms they cause. Relatively more research information is available on diseases caused by fungi than that of bacteria, viruses and nematodes because of lack of trained human power as well as laboratory facilities.

This paper reviews research achievements of the past twenty years, identifies gaps and suggests future research directions in the area of vegetable pathology research and development.

# Research findings

## Diseases recorded

### Fungal diseases

Several field surveys were made to assess fungal diseases of vegetable crops in the past two decades. Most of the diseases found in the country were compiled by Tesfaye and Habtu (1985). More recently several workers also reported various vegetable diseases (Mengistu and Seid, 1991; Mengistu, 1994; Mohammed and Getachew, 1995; Temam, 2006). The major fungal diseases of vegetables in this country include gray mold (*Botrytis cinerea*) and pod rot (*Phytophthora* sp.) on snap beans; powdery mildew (*Leveillula taurica*), Fusarium wilt (*Fusarium oxysporum*) and southern blight (*Sclerotium rolfsii*) on pepper; basal rot (*Fusarium* spp) and downy mildew (*Perenospora destructor*) on onion/ shallot; garlic rust (*Puccinia allii/ P. porrii*) and white rot (*Sclerotium cepivorum*) on Allium. These are only a few of highly widespread diseases found in vegetable producing areas of the country (Mengistu, 1994; Mohammed and Somsiri, 2005; Temam, 2006). Mohammed et al (2006) reported tomato powdery mildew (*L. taurica*) and gray mold of snap beans (*B. cinerea*) to be new records. However, tomato powdery mildew has been a minor problem in the past. Currently this disease is becoming a major production constraint on irrigated tomatoes. BARC (2000) reported wilt disease of hot pepper caused by *Rhizoctonia solani* and *Fusarium* spp. attacking stem and roots in Bako and Nejo areas, western Ethiopia. In addition, pod rotting caused by *Phytophthora infestans*, frogeye leaf spot *(Cercospora capsici*) and pod bleaching (assumed to be caused by fungi and insect damage) were found to be important in the region with severity ranging from 3-5 (based on 1-9 scale).

Shallot is attacked by basal rot disease caused by *Fusarium oxysporum* f.sp. *cepae*. A survey conducted in East Shewa Zone (Ada, Lume-Bora, Minjar-Shenkora, Huruta) showed basal rot incidence of 1-5% in farmer's fields and up to 34% in the Debre Zeit Agricultural Research Center (DZARC, 1994; Negussie *et al*., 1993). Downy mildew (*Perenospora destructor*) was also found to causing severe damage in a farm near Arsi Negelle, while purple blotch (*Alternaria porri*) was observed in almost all fields. Both diseases were serious problems at the research center as well. Recent surveys (1997-1999) in northern Ethiopia also revealed that these diseases were important in major shallot growing areas.

## Nematode diseases

The first comprehensive nematode survey was done in 1974 by the FAO expert (O'Bannon, 1975) who identified six nematode genera and species infecting tomato, lettuce, sweet pepper, onion and sweet basil. These are *Helicotylenchus* spp., *Heterodera* sp. *Meloidogyne incognita, M. ethiopica*, *Pratylenchus* spp. and *Tylenchus* spp.

Wondirad and Tesfamariam (2002) made an extensive survey of the root-knot nematodes on different vegetable crops in the central, south and western parts of Ethiopia from 1998 to 2000, and found that the nematodes were highly distributed in all areas (Tables 1 and 2). The incidence on pepper was high followed by tomato and onion. The most common nematode was *M. incognita* followed by *M. ethiopica* and *M. javanica* in that order, in both 1998/99 and 1999/2000 seasons. The level of mixed infection was also high in the 1999/2000 season accounting for 32.7% for *M. incognita* mixed with *M. ethiopica*, while *M. incognita* mixed with *M. javanica* was only 3.9% (Wondirad and Tesfamariam, 2002).

Tadele and Mengistu (2000a) reported that *M incognita* was the only species widely distributed in eastern Ethiopia. Studies on the relationship among nematode distribution and altitude, soil texture and pH indicated that population density of root-knot nematode increased as the sand content and pH of the soil increased ($r = 0.88$, $P<0.01$; $r = 0.54$, $P<0.05$), respectively, whereas, clay and silt content of the soil and altitude showed an inverse relationship to population density ($r = -0.88$, $r = -0.74$ and $r = -0.83$, $P<0.01$), respectively.

Table 1. Percentage occurrence of root-knot nematodes and mean root-knot index on different vegetables in 1998/99 crop season (after Wondirad and Tesfamariam, 2002).

| Vegetables | Fields visited (No.) | No. fields with root-knot nematodes | Occurrence (%) | Total samples | Mean root-knot index |
|---|---|---|---|---|---|
| Tomato | 46 | 28 | 60.9 | 148 | 2.5 |
| Pepper | 29 | 18 | 62.1 | 89 | 2.8 |
| Onion | 15 | 5 | 33.3 | 46 | 1.6 |
| Snap bean | 5 | 3 | 60 | 16 | 2.4 |
| Cabbage | 3 | 2 | 66.7 | 14 | 1.8 |
| Beet root | 1 | 1 | 100 | 5 | 1 |
| Carrot | 1 | 1 | 100 | 5 | 1 |
| Potato | 2 | 1 | 50 | 2 | 2 |
| **Total** | 102 | 59 | 57.8 | 384 | |

Table 2. Occurrence of root-knot nematodes and root-knot index on different vegetables in the 1999/000 crop season (Wondirad and Tesfamariam, 2002).

| Vegetables | No. fields visited | No. fields with root-knot nematode | Occurrence (%) | Total samples | Mean root-knot index |
|---|---|---|---|---|---|
| Tomato | 17 | 8 | 47.1 | 78 | 1.5 |
| Pepper | 45 | 36 | 80 | 232 | 1.6 |
| Onion | 17 | 8 | 47.1 | 83 | 0.9 |
| Snap bean | 3 | 2 | 66.7 | 16 | 0.8 |
| Cabbage | 4 | 2 | 50 | 15 | 0.9 |
| Beet root | 2 | 2 | 100 | 11 | 4.2 |
| Carrot | 1 | 1 | 100 | 4 | 1.8 |
| Potato | 1 | 1 | 100 | 5 | 1.8 |
| **Total** | 90 | 60 | 66.6 | 444 | |

## Virus diseases

During the dry season (January to February) and rainy season (August to September) of 1994, small irrigated and rain fed fields of tomato and hot pepper at Melkassa, Wonji, Guder, Bako, Ziway, Shashamane, Wondo Genet, Wolisso, and large-scale tomato farms at Merti were inspected for virus disease symptoms. Leaf and pod samples (286 pepper and 222 tomato) with virus-like symptoms, and samples from *Datura stramonium* and *Nicandra physaloides* weeds near or within the tomato fields were collected and analyzed using enzyme linked immunosorbent assay (ELISA), mechanical inoculation to test plants and electron microscopy (EM) (Yaynu, 1998).

The **s**amples were analyzed using 26 antisera and monoclonal antibodies (MAbs) in double antibody sandwich (DAS)-ELISA and triple-antibody sandwich (TAS)-ELISA against viruses known to infect pepper and tomato in other countries (Yaynu, 1998). Viruses detected from pepper samples by ELISA are shown in (Tables 3 and 4). Of the 286 samples analyzed, 207 (72.3%) positively reacted with antisera to Chilli veinal mottle virus (CVMV), *Potato virus* Y (PVY), *Tomato mosaic virus* (ToMV), *Pepper veinal mottle* virus (PVMV) and MAbs 3C2 and P-3-3H8. The DAS-ELISA reactions of the CVMV antiserum with many hot pepper samples were weaker than with the homologous CVMV but was as strong as with the *Ethiopia pepper mottle virus* (EPMV)-PN1, a potyvirus isolate previously reported from Ethiopia by Mitiku (1986) and Agranovsky (1993). Therefore, all samples giving intermediate reactions with the CVMV antiserum were tentatively referred here to as EPMV infected samples. The broad spectrum MAb P-3-3H8 reacted with all those samples that gave reactions with the PVY, CVMV and PVMV antisera, confirming the presence of potyviruses in the samples. In contrast, MAb 3C2 reacted only with PVY- positive samples and thus corroborated the presence of

PVY. Recently, analysis of samples collected from Awassa showed infections caused by *Cucumber mosaic virus* (CMV) and Potato virus X (PVX) in pepper (Tamiru, 2004).

Of the 207 hot pepper samples found infected with at least one virus, PVY and EPMV appeared to be the predominant, as EPMV, PVY and mixed infections with EPMV and PVY were detected in 24, 36, and 27% of the samples, respectively. Even higher incidence of EPMV was reported in the later surveys in the rift valley (Tamiru, 2004). Of the 503 pepper samples analyzed, 60% were infected with EPMV followed by PVY 23%. Two other viruses PVMV and ToMV were also detected but in a limited number of samples and in a few locations in both single and mixed infections. For instance, PVMV was detected in 11 samples from the Bako area in western Ethiopia and ToMV in nine samples from the Rift Valley (Yaynu, 1998; Yaynu et al., 1999) (Table 3). Shih et al. (2005) found the whitefly transmitted *Tomato yellow leaf curl virus* be the most important disease of tomato in the country, particularly in the Rift Valley areas including Upper Awash. Research efforts are underway for its accurate identification and management including the use of chemicals to control the vector.

Table 3. Occurrence and distribution of viruses infecting hot pepper during the rainy and dry seasons of 1994 (after Yaynu, 1998).

| **Location** | **Samples collected** | **Type of viruses** | | | | | | **Infected samples** |
|---|---|---|---|---|---|---|---|---|
| | | **EPMV** | **PVY** | **EPMV / PVY** | **EPMV, PVY, ToMV** | **PVMV** | **ToMV** | |
| Rift Valley | | | | | | | | |
| Melkassa | 48 (R) | 8 | 16 | 12 | 2 | 2 | 3 | 41 (85.4)[1] |
| Wonji | 25 (D) | 10 | 4 | 8 | - | | - | 22 (88.0) |
| Ziway | 35(R) | 9 | 6 | 14 | 2 | - | 2 | 33 (94.3) |
| | 27 (D) | 2 | 7 | 7 | | | 3 | |
| Shashmane | 30 (R) | 4 | 9 | 10 | - | - | 1 | 23 (76.7) |
| and Wondo Genet | 15 (D) | 3 | 6 | - | - | - | - | 10 (71.4) |
| Marako | 28 (R) | 4 | 10 | 6 | - | | | |
| W. Ethiopia | | | | | | | | |
| Guder | 24 (R) | 8 | 5 | - | - | - | - | 13 (54.2) |
| Bako | 54 (D) | 2 | 13 | - | - | 11 | - | 26 (48.1) |
| Total | 286 | 50 | 76 | 57 | 4 | 11 | 9 | 207 (72.3) |

R: rainy and D: dry seasons, [1] Figures in parentheses are percentage of virus – infected samples collected in each area.

Table 4. Occurrence and distribution of viruses infecting tomato during January - February, 1994 (Yaynu, 1998).

| Location | Virus host species | No. samples | Type of viruses | | | | No. of infected samples |
|---|---|---|---|---|---|---|---|
| | | | TMMV | PVY | TMMV and PVY | ToMV | |
| Rift valley | | | | | | | |
| Ziway | Tomato | 42 | 20 | 4 | 4 | 5 | |
| | *Dautra stramonium* | 11 | 4 | - | - | - | 40(67.8) [1] |
| | *Nicandra physalodes* | 6 | 3 | 3 | - | - | |
| Koka | Tomato | 21 | 10 | 3 | _ | _ | 15(60.0) |
| | *Dautra stramonium* | 4 | 2 | _ | 8 | _ | |
| Melkassa | Tomato | 48 | 9 | 5 | 8 | _ | 27(49.1) |
| | *Datura stramonium* | 7 | 5 | - | | _ | 8(36.4) |
| Wondo Genet, Merti | Tomato | 22 | 4 | 2 | - | 2 | 8( 19.5) |
| | Tomato | 41 | 8 | - | - | - | |
| ***Western Ethiopia*** | | | | | | | |
| Guder, Bako and Wolliso | Tomato | 16 | 3 | 3 | - | - | 8(40.0) |
| | *Datura stramonium* | 4 | 2 | - | - | - | |
| Total | | 222 | 70 | 17 | 12 | 7 | 106(47.7) |

[1] Figures in parentheses are percentage of virus – infected samples collected in each area.

# Basic studies

## Fungal diseases

According to Nigussie *et al*. (1993), light soil (Alfisol/Mollisol) seems to favor development of basal rot of shallot than Pelvic Vertisol. Interviewed farmers also confirmed that basal rot had been a problem on light soils (DZARC, 1994). On the other hand, studies on the incidence of basal rot caused by *Fusarium oxysporum* on two soil types (Alfisol/Mollisol and Vertisol) indicated that soil types did not differ significantly (Table 5). However, significantly higher fresh bulb yield was obtained from the vertisol which could be due to the relatively high fertility status and/ or due to the longer growing period required for plants to reach maturity. Better crop establishment was recorded on the light soil. Moreover, the interaction between soil types and cultivar was not significant (DZARC, 1997).

Twenty-seven garlic clones (14 from Debre Zeit and 13 from Arsi and Shewa areas) collected in 1987 in cooperation with the PGRC/E and evaluated for their resistance to disease in 1988 at DZARC showed that all of the collections were

susceptible to garlic rust and other unidentified diseases (DZARC, 1988). Moreover, yield loss assessment study on frogeye leaf spot (*Cercospora capsici*) carried out on hot pepper at BARC during the 1990/91 season showed that there was 26.1% yield loss on the variety Bako local.

Table 5. Mean fresh yield, yield/plant, stand count, and bulb rot incidence on ten shallot cultivars on two soil types at Debre Zeit (DZARC, 1997) (DZARC, 1997).

| Cultivars | Mean fresh yield (q/ha) | | | Yield/plant (g) | | | Stand count (%) | | Bulb rot incidence | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Alfisol | Vertisol | Mean | Alfisol | Vertisol | Mean | Alfisol | Vertisol | Alfisol | Vertisol |
| DZSHT-16 | 75.0 | 107.8 | 91.4 | 74.0 | 111.6 | 92.8$^{ab}$ | 90.3 | 89.4 | 2.3 | 2.1 |
| DZSHT-21 | 80.1 | 107.3 | 93.7 | 76.3 | 103.7 | 90.0$^{ab}$ | 92.0 | 86.0 | 2.5 | 2.4 |
| DZSHT-22 | 80.1 | 111.4 | 95.8 | 81.5 | 116.9 | 99.2$^{a}$ | 88.4 | 84.6 | 2.3 | 2.3 |
| DZSHT-23 | 82.4 | 114.1 | 98.3 | 75.3 | 103.0 | 89.2$^{ab}$ | 91.2 | 88.3 | 2.4 | 2.3 |
| DZSHT-61 | 81.1 | 94.7 | 87.9 | 75.9 | 91.3 | 83.6$^{abc}$ | 89.5 | 79.1 | 2.3 | 2.3 |
| DZSHT-68 | 87.9 | 118.4 | 103.2 | 81.9 | 106.6 | 94.3$^{a}$ | 95.8 | 86.3 | 2.3 | 2.4 |
| DZSHT-78 | 81.7 | 102.3 | 92.0 | 82.6 | 107.6 | 95.1$^{a}$ | 90.3 | 84.2 | 2.3 | 2.7 |
| DZSHT-82 | 64.1 | 94.9 | 79.5 | 49.5 | 87.0 | 68.3$^{c}$ | 93.2 | 89.9 | 2.1 | 2.2 |
| DZSHT-91 | 72.5 | 91.4 | 82.0 | 70.7 | 91.8 | 81.3$^{abc}$ | 92.1 | 86.5 | 1.9 | 2.2 |
| DZSHT-124 | 65.3 | 87.6 | 76.5 | 64.9 | 80.7 | 72.8$^{bc}$ | 91.1 | 83.1 | 2.5 | 2.1 |
| Mean | 76.7$^{b}$ | 103.6$^{a}$ | 90.2 | 73.0$^{b}$ | 100.0a | 86.7 | 91.3$^{a}$ | 85.8$^{b}$ | 2.3 | 2.9 |
| LSD (0.05) | | | 25.3 | | | 22.0 | | | | |
| CV (%) | | | 38.9 | | | 35.3 | | | | |

Means followed by the same letters within a column or within a row for the parameter are not significantly different at 5% level by DMRT and LSD respectively.

## Plant parasitic nematodes

Studies were conducted to determine the damage potential of *M. incognita* and *M. javanica* on different cultivars of tomato, pepper and maize (Tesfamariam et al., 2002; Tesfamariam et al., 2003). The study made with a susceptible "Marmande" and resistant "Beaufort" cultivars of tomato and hybrid maize showed that the damage threshold was about 1.6 juveniles/cm$^3$ of soil ($r^2$ = 0.87) for the susceptible tomato while the Seinhorst model could not fit for resistant tomato and maize (Tesfamariam et al., 2002). Similarly, the data on *M. javanica* using the local tomato variety "Marglobe" and pepper "Marekofana" fitted the Seinhorst model with ($r^2$ = 0.96) and ($r^2$ = 0.94), and tolerance limit of 0.28 and 0.36 juveniles/cm$^3$, respectively (Tesfamariam et al., 2003). The result is clear enough to show the high damage potential of these nematode species to vegetables.

Field populations of *Meloidogyne* spp. collected from different parts of the country and maintained in the greenhouse were analyzed for cytogenetic and esterase isozyme variability (Wondirad and Kifle, 2000b). Results showed high

intra-population and intra-specific variability in chromosome number in the populations of *M. incognita* and *M. ethiopica*. In both species, diploid numbers of 36–38 and hypertriploid number of 40–46 chromosomes were counted. *M. javanica* showed less variability and had a hypertriploid chromosome number of 40–46. Except for *M. ethiopica*, which is not studied before, the result was similar to the studies made elsewhere. *M. incognita* and *M. ethiopica* had two chromosome races, each having distinct set of chromosome numbers, while the *M. javanica* had only one race (Wondirad and Kifle, 2000b).

Fifty three populations of *Meloidogyne* spp. analyzed for esterase isozyme patterns revealed that *M. incog*nita and *M. javanica* had one phenotype with distinct banding patterns called I1 and J3, while *M. ethiopica* had two phenotypes E3 and E2. E3 was a smeared pattern and species specific which can be used for diagnosis (Wondirad and Kifle, 2000b). *M. ethiopica*, which is not commonly found in many parts of the world except in Africa could easily be identified with these patterns.

*Meloidogyne* is the most diverse genus in several morphologic characters used for species identification. Studies of 50 populations of the three species in the country have shown that perianal pattern, the main character used to separate species, is highly variable among populations (Wondirad and Kifle, 2000a). *M. incognita* exhibited extensive variation whereas less variation was observed in populations of *M. javanica* and *M. ethiopica*. Species identification using this feature, thus, requires quite an experience. In addition, the stylet (spear like structure used to pierce plant cells and tissues) length of populations of *M. javanica* and *M. ethiopica* obtained from enset was found to be significantly ($P = 0.05$) larger than the other species suggesting a possible form of an adaptation. Similar observation was previously made on several nematode species when cultured in different food sources in artificial media (Wondirad et al, 2003). These variabilities are intrinsic within the genus and are associated with species highly specialized as plant parasites.

## Viruses

**Electron microscope (EM):** Some of the major plant viruses identified in the country were studied using electron microscope. Samples of pepper and tomato were also analyzed using 26 antisera and monoclonal antibodies (MAb) against viruses known to infect pepper and tomato in other countries (Yaynu, 1998; Yaynu and Vetten, 2000; Yaynu et al., 1999). Filamentous and rod-shaped particles typical of potyviruses and to bamoviruses, respectively, were detected in field samples from tomato and pepper. Mixed infections of pepper samples with PVY or EPMV and ToMV were verified by EM.

**Inoculation to test plants:** Test plants were grown in an insect–free greenhouse at 20-25$^{o}$C with 16 hr day light. Extracts were inoculated onto 3- 5 carborundum dusted leaves of young plants each of *Capsicum annum* cv. Yolo Wonder, *Nictiana benthamiana* Domin, *N. clevelandii G*ray, *N. glutinaosa* L., *N. tobaccum* L., cv. White Burely, *Datura metel* L. and tomato cv Linda. Plants were monitored for symptom development for at least three weeks. The presence of viruses in test plants was determined by testing inoculated and non–inoculated top plants by ELISA. All samples originated from tomato as well as *D. stramonium* and *N. physaloides* weeds confirmed the DAS-ELISA reactions and revealed four additional infections in tomato. Thus 110 (49.5%) samples induced symptoms on all or some of the test plants as shown in Table 7. Tomato mild mottle virus (TMMV) induced vein clearing followed by leaf deformation or stunting in all test plants. PVY induced vein clearing and severe stunting in *N. clevelandii*, vein clearing followed by mosaic in other *Nicotiana* spp.,and mosaic in tomato two weeks after inoculation. *D. stramonium* was immune to PVY, providing a means to separate TMMV and PVY in mixed infections (Table 6). ToMV caused leaf mosaic on tomato cv. Linda and was readily identified by its symptoms on most of the solanaceous species by reacting with necrotic local lesions 3-4 days after inoculations (Yaynu et al., 2001). Extracts from pepper samples inoculated onto test plants induced symptoms supporting ELISA reactions. DAS-ELISA conducted on inoculated and non-inoculated top leaves revealed systemic infections with EPMV, PVY and PVMV (Table 7). Potyviruses found predominant in the diagnosis of the samples collected from pepper and tomato in Ethiopia were further characterized using conventional and molecular methods (Yaynu, 1998). The conventional methods include host range, cytopathological effects, physicochemical analysis, aphid transmission and serological reaction studies. The results obtained in both methods were similar and or compatible.

**Host range study:** Table 10 shows the reactions of 19 solanaceous species (belonging to seven genera) subjected to mechanical inoculations with the isolates 374/94, 430/94 and EPMV-PN1 from pepper samples, and the reactions of 20 solanaceous to PVY from tomato and TMMV isolates from tomato and *D. stramonium* are listed in Tables 9. As shown in Table 10 with the exception on two tobacco genotypes, local and/or systemic infections with at least one of the isolates 374/94, 430/94 and EPMV-PN1 were obtained in all the tested solanaceous species. Two TMMV isolates infected the same 17 species with indistinguishable symptoms. TMMV differed from the PVY isolate by infecting *Datura* spp. and *S. indicum*, while PVY infected *Chenopodium quinoa,* Yolo Wonder and pepper variety Mareko Fana, all of which appeared to be immune to TMMV.

Table 6. Reaction of test plants upon inoculations with samples infected with Different viruses (.Yaynu, 1998).

| Test plant | Test plant reactions to [a] inoculation with | | |
|---|---|---|---|
| | **PVY** | **TMMV** | **ToMV** |
| *D. stramonium* | - | VC,Mo | NLL |
| *L.esculentum cv* Linda | M | Mo,St | M,St [b] |
| *Nicotiana benthamiana* | VC,Vb,Ld | VC,Ld | NLL, Pd |
| *N. clevelandii* | VC,M,St | VC,St | St [b],Pd |
| *N. glutinosa* | VC,M | VC,St,Ld | NLL,Pd |
| *N. sylvestris* | n.t.. | VC,St | NLL |
| *N. tobaccum* 'White Burely' | VC,M | VC,Mo | NLL,Pd |

[a] Ld, leaf distortion; M, mosaic , Mo, Mottling; NLL, necrotic local lesion; Pd, plant death; St, stunting; VC, vein clearing; -, not infected; n.t, not tested.
[b] ToMV detected in inoculated and non- inoculated leaves.

Table 7. Reactions of test plants upon inoculations with samples of PVY, EPMV, PVMV andToMV (Yaynu, 1998).

| Test plants | Viruses inoculated | | | |
|---|---|---|---|---|
| | **PVY** | **EPMV** | **PVMV** | **ToMV** |
| *D. metel* | Moc | Mo, Ld | Mo | n.t. |
| *L.esculentum cv* Linda | Mo | - | Mo, St | M,St [b] |
| *C.annum Yolo Wonder* | M,St | M, Ld | Mo | M,St [b] |
| *N. benthamiana* | VC, M, Ld | VC, M,Ld | VC, Ld | NLL,Pd |
| *N. clevelandi* | VC, M, St | VC,M,St | VC,M | St,Pd |
| *N. glutinosa* | VC, M | - | VC,Mo | NLL,Pd |
| *N. tobaccum* | VC,M | - | - | NLL,Pd |

[a] Ld, leaf distortion; M, mosaic, Mo, Mottling; NLL, necrotic local lesion; Pd, plant death; St, stunting; VC, vein clearing;. -, not infected at all; n.t, not tested.
[b] ToMV detected in inoculated and non- inoculated leaves.

**Cytopathological effects:** Cytopathological effects in infected cells which are used for characterization and differentiation of potyviruses were determined for isolates 374/94, 430/94, EPMV-PN1 and TMMV from tomato 277/94 (Yaynu, 1998). Similarly, cytopathological effects of EPMV isolates were recently determined by Tamiru (2004). The isolates differed in the production of cytoplasmic aggregates in infected cells. Isolate 374/94 produced pinwheel elements consisting of conspicuous scrolls with short, curved and laminated aggregates, while isolate 430/94 and EPMV-PN1 produced indistinguishable cytoplasmic inclusions (CI) and weakly developed scrolls (Yaynu, 1998). However, Tamiru (2004) reported CI comprising well developed pinwheels and scrolls from EPMV-bod3 isolate. In the imbedded material studied, CI was rarely found in TMMV isolate 277/94 infected tissues

probably due to the extremely low particle concentration in the crude extracts (Yaynu, 1998; Yaynu et al., 2001).

Table 8. Test plant reactions to mechanical inoculation with different potyviruses (after Yaynu, 1998 and Tamiru, 2004).

| **Host species** | **Reactions to different potyviruses** | | | | |
|---|---|---|---|---|---|
| | **374/94** | **430/94** | **EPMV-PN1** | **CVMV 1037** | **PVMV** |
| *C. anuum* Yolo Wonder | L/M,G | L/M,Vb | L/M,Vb | L/Sn | L/Mo |
| *C. frutescens*' Bako local | M | Mo, St,Vb | Mo, St Vb | Pd | Si |
| *C. frutescens*'cv Marekofana | VC, Ld | M, Ld | M,Ld | Pd | Si |
| *Datura metel* | L/VC,M | L/VC,M | L/VC,M | - | L/VC,M |
| *D. stramonium L* | L/Mo | L/Sn | L/Sn | L/Sn | L/M |
| *Lypersicum lycpersicom,*' linda | L/St | - | - | - | L/M |
| *Nicandra physaloides* | L//St | L/St | - | L/M | L/M,St |
| *Nicotiana benthamiana* | L/VC,Ld | L/VC,Ld | L/VC,Ld | L/VC,Ld | L/VC,Ld |
| *N. clevelandii* | Cs/ VC,M | Cs/VC,St | Cs/VC,M | Cs/VC,St | Cs/VC,St |
| *N. debenyi* | - | - | L/M | L/\St | L/Scs |
| *N. glutinosa* | Cs/VC | - | - | Cs/M. | Cs/M |
| *N. hesperis* | Cs/ Scs | Cs/ Scs | Cs/ Scs | n.t. | Cs/M |
| *N. megalosiphon* | Cs VC,Ld | Cs VC,Ld | Cs VC,Ld | Cs VC,Ld | _ |
| *N. miersii* | LL | L/Sc | L/Sc | L/Sc | L/Scs |
| *N. occidentalis* | LL, D | Cs/VC | Cs/VC | Cs/VC | Cs/VC |
| *N .rustica* | L/- | LL | L/Ld | L/Ld | - |
| *N. tabacum. Samsun NN* | - | - | - | L/Sc | - |
| *N. tobaccum White Burely* | - | - | - | L/sn | L/Scs |
| *Physalis flordana* | L/Scs, D | L/Scs, D | L/Scs,D | L/Scs,D | L/Scs,D |
| *Solanum demissum* | - | - | - | St | - |

[a] Symptomless infection of inoculated leaves. Reaction on the upper leaves were: Cs, Chlorotic spot; Scs, systemic chlorotic spots, G, green spots; Pd, plant death; Ld, leaf deformation, LL, local lesion; Mo, leaf mottle; M, leaf mosaic; Vb, vein banding; St, symptomless infection; Sn, systemic necrosis; necrosis; St stunting; VC, vein clearing, - no symptoms, and-, n.t, not tested.

Table 9. Test plant reactions to inoculation with TMMV isolates from tomato and *D. stramonium* and with an Ethiopian PVY isolate from tomato (Yaynu, 1998; Tamiru, 2004).

| Test plants | Reaction [a] to | | |
|---|---|---|---|
| | 246/94 | 277/94 | PVY |
| **Chenopodiaceae** | | | |
| *Ch. gunoa* | - | - | LL |
| **Solanaceae** | | | |
| *C. anuum* Yolo Wonder | - | - | M |
| *C. frutescens*'cv Marekofana | - | - | M |
| *Datura metal* | VC,M | VC,M | - |
| *D. stamonium L* | VC,M | VC,M | - |
| *Lypersicon lycpersicom* ' linda | Mo | Mo | M |
| *Nicandra physalodes* | Mo | Mo | M |
| *Nicotiana benthmiana* | VC,M | VC,M | VC,M |
| *N. clevelandii* | VC | VC | M |
| *N. debenyi* | VC | VC | VC |
| *N. glutinosa* | VC,St | VC,St | M |
| *N. megalosiphon* | Vc,D | Vc,D | M,St |
| *N. occidentalis* | LL, D | LL, D | VC |
| *N. rustica* | VC, Mo | VC, Mo | VC |
| *N. tobaccum cv. Samsun* NN | VC, Mo | VC, M | Mo |
| *N. tobaccum cv. Samsun* NN | VC | VC | VC,M |
| *N. tobaccum cv. White burely* | VC | VC | VC |
| *N. tobaccum cv. Xanthi* NC | VC | VC | Mo |
| *Physalis flordana* | Sn | Sn | - |
| *Solanum demissum* | Ld | Ld | |

- = Not infected; D, death of the plant; Ld, leaf deformation; LL, local lesion, M, leaf mosaic, Mo, Mottling, Sn, systemic necrosis,VC, vein clearing, St, stunting.

**Aphid transmission:** Using 30 apterous aphids per plant, pepper isolates 374/94 and 430/94 and the tomato isolate 277/94 were efficiently transmitted in a non-persistent manner by *Myzus persicae* in all combinations of source and recipient host plant species (Tables 10 and 11) (Yaynu, 1998).

Table 10. Transmission of the hot pepper isolates 374/94 and 430/94 by *Myzus persicae* from various sources to different recipient host plant species (Yaynu, 1998).

| Virus isolates and recipient hosts | Virus source plant species | | |
|---|---|---|---|
| | Mareko fana, *C. frutescens* | *D. metel* | *D. stramonium* |
| 374/94 | | 3/3 | 2/2 |
| *C. frutescens* Mareko fana | 3/3[a] | 3/3- | 3/3 |
| *D. metel* | 3/3 | 2/2 | 2/2 |
| *D. stramonium* | 3/3 | | |
| 430/94 | | | |
| *C. frutescens* Mareko fana | 3/3 | 3/3 | 3/3 |
| *D. metel* | 3/3 | 2/2 | 3/3 |
| *D. stramonium* | 2/2 | 2/2 | 2/2 |

[a] Number of infected and ELISA- positive plants/total number of plants tested, using 30 apterous aphids per plant.

Table 11. Transmission of TMMV- 277/94 by *M. persicae* from various sources to different recipient host plant species (Yayinu, 1998).

| Recipient host plant species | Virus source plant species | | | |
|---|---|---|---|---|
| | ***D. metel*** | ***D. stramonium*** | ***N. glutinosa*** | **Tomato'Linda** |
| *D. metel* | 2/2[a] | 2/2 | 3/3 | 2/2 |
| *D. stramonium* | 3/3 | 2/2 | 0/3- | 2/2 |
| *N. glutinosa* | 3/3 | 0/3 | 3/3 | 3/3 |
| Tomato Linda | 3/3 | 3/3 | 3/3 | 3/3 |

[a] number of infected and ELISA- positive plants/total number of plants tested, using 30 apterous aphids per plant.

**Serological relationship as determined by DAS-ELISA**: The predominant pepper and tomato potyvirus isolates were tested in homologous and heterologous combinations using a total of 11 antisera. Antisera to 374/94 and PVMV gave strong DAS-ELISA reaction only in homologous combinations and with PVMV and isolate 374/94, respectively. The antisera to isolate 430/94 and EPMV-PN1 yielded strong and indistinguishable reactions in homologous combinations, and with all Ethiopian pepper isolates except 374/94 and PVY-356, suggesting that isolate 430/94 and EPMV-PN1 together with most of the other Ethiopian isolates were serologically very closely related (Yaynu et al, 2001).

Tamiru (2004) also found potyviruses collected from some districts of the Rift Valley were serologically indistinguishable with EPMV-PN1 and 430/94 showing that the EPMV is widespread and important virus in the pepper growing areas of the Rift Valley**.** The Yemeni and Ethiopian isolates of TMMV reacted very strongly not only in homologous combinations but also with four other Ethiopian potyviruses from tomato, *D. stramonium* and *N. physaloides* indicating that they all are serologically closely related and indistinguishable (Yaynu, 1998; Yaynu et al., 1999; 2001).

**Molecular characterization**: Coat protein (CP) amino acid and 3′ non translated region (NTR) nucleotide sequence comparisons were carried out for the pepper isolates. Ethiopian isolates 374/94, CVMV-1037 and PVMV were partially sequenced and compared to one another and with sequences of other potyviruses for taxonomic purposes (Yaynu, 1998). Multiple alignments of CP amino acid sequences of 374/94, CVMV-1037, PVMV showed a higher identity in C-terminal and the core regions than in the N-termini, a characteristic of all potyviruses. The CP amino acid sequence similarities between CVMV-1037 and other potyviruses ranged from 55 to 96% with chilli veinal banding mottle virus (CVbMV) being the most similar. The CP amino acid sequence similarity between 374/94 and PVMV was 91% confirming their close biological and serological relationships discussed earlier. Isolate 374/94

should be regarded as strain of PVMV in spite of its relatively low identity of 70% in 3′-NTR. Moreover, CVMV-1037 had a CP amino acid and 3′-NTR sequence similarity of 96% and 85%, respectively implying CVbMV to be equal to CVMV. This shows a striking identity with CVMV of the 16 and 18 N-terminal amino acid residues of presumably undegraded CP and the tripsin-resistant core CP of CVMV (Yaynu, 1998).

# Disease control studies

## Chemical control of bacterial diseases

Screening of chemical pesticides for the control of bacterial diseases of hot pepper (variety Bako local) was conducted at the Bako Agricultural Research Center with treatments: Kocide 77% WP, Vitagram Blue 85% WP, Champion 77% WP, Bordeaux M-80% WP and Nabac 25% EC, all at two rates, antibiotics (not known), Clorox solution and untreated check were compared for effectiveness against bacterial diseases of hot pepper (Bako local) at Bako, and results were found to be inconsistent in that Bordeaux M-80% WP at 2 kg/ha was effective in the first year while Cobox 59% WP at 0.88 and 1.18 kg a.i./ha was more effective in the second year (BARC, 1988; 1990).

## Fungal diseases

**Host plant resistance against major foliar diseases:** Forty-two tomato cultivars were evaluated for their resistance/tolerance to major foliar diseases at Melkassa. Among the tested tomato cultivars Floradade, Arizona, CL-5915-206-D4-2-3-0, CL-5915-553-D4-3-0, Heinz 1350 Sel. Mexico, Bl-444 (Vc294A, Solar set hybrid, Red Ball, Nova At-30) were found to be relatively tolerant to the major leaf diseases such as late blight (*P. infestans*), early blight (*Alternaria solani*) and powdery mildew (*Leveillula taurica*) (MARC, 2000). Tomato cultivars introduced from the Asian Vegetable Research and Development Center (AVRDC)/Tanzania (Marglobe 2009, Tengeru 97), and MARC showed lower severity (3-4 in a 1-9 scale) of late blight.Yield advantages of 96%, 60% and 50%, respectively, were recorded over the standard variety Marglobe both on station and verification trials under farmers conditions (Mohammed, 2002).

**Damping off:** Damping off is caused by a complex of fungal pathogens such as *P. infestans*, *Phythium* spp., *Fusarium* sp. and *Rhizoctonia* sp. Such pathogens are known to be soil borne and cause serious damage at the early stage of seedling establishment of tomato and pepper on seedbeds. Research conducted at MARC to manage the problem of damping off in seedbeds using

cultural methods, heat treatment and seed dressing chemicals. Soil solarization of seedbeds for 30 days using black polythene sheets, burning of sorghum/maize stalk on the seedbed and seed dressing using Apron star and Thiram gave better seedling establishment and reduced seedling infection by damping off pathogens (Table 12). All control measures were verified on farmers' fields around Wonji as alternative disease management options with the involvement of vegetable farmers as research partners. Farmers appreciated the effect of soil solarization and burning as components of integrated pest management options. As a result, vegetable farmers easily adopted soil solarization for the control of damping off on tomato and pepper. Apart from their effect on damping off, solarization of seedbeds using polythene sheets and burning of seedbeds using maize/sorghum stalks reduced weed infestation (Mohammed, 2002).

Table 12. Cultural and chemical control of damping off on tomato (Mohammed, 2002).

| Treatments | Seedling establishment (%) | Seedling infection (%) |
|---|---|---|
| Soil solarization | 82.0 | 11.5 |
| Burning | 88.0 | 12.0 |
| Hot water | 67.0 | 38.0 |
| Thiram | 78.0 | 35.0 |
| Apron star | 84.0 | 21.0 |
| Control | 62.0 | 56.0 |
| Mean | 76.8 | 28.9 |
| C V | 14.6 | 16.0 |

**Chemical control of late blight on tomato**: Fungicides were screened for the control of late blight in the Central Rift Valley area. Potential fungicides were also verified on farmers' fields around Melkassa, Ziway and Wondo Genet. Three fungicides (Metalaxyl-M4% + Mancozeb 64% (Ridomil Gold 68 WP) 350g/100litre, Fungomil 250 gm/100litre, and Mancozeb + Metalaxyl (Mancolaxyl 72%) 250g/100litre) were found effective in controlling the disease on tomato and consequently increased marketable fruit yield by 40-66% (Table 13).

**Purple blotch on onion/shallot**: Purple blotch caused by the fungus *Alternaria porri* is a major threat of onion/shallot production in the country. This pathogen is known to be seed borne. The disease is more destructive during the rainy season with high soil moisture and humidity.

Application of fungicides (Mancozeb 50% WP at 3 kg/ha as protective, and Ridomil Gold MZ 68% WP at 2.5 kg/ha as curative significantly reduced severity of purple blotch and increased bulb yield of onion and shallot (MARC, 2000).

Table 13. Effect of fungicide spray on the severity of late blight and yield of tomato (MARC, 2000).

| Treatments | Severity (1-6) | Marketable yield (q/ha) |
|---|---|---|
| Ridomil Gold | 2.3 | 250 |
| Famoxate | 2.8 | 175 |
| Mancolaxyl | 2.0 | 233 |
| Fungomil | 3.8 | 210 |
| Uthane M-45 | 3.0 | 208 |
| Control | 4.3 | 150 |
| Mean | 2.8 | 204 |
| C V | 15.8 | 18.7 |

Two fungicides Chlorothalonil 50% FW or 75% WP and Aspor 70% WP at 1.25, 1.75 and 2.25% and at concentrations of 0.2, 0.3 and 0.4% were tested against purple blotch of onion variety Adama Red at Bako (Table 14). Low disease incidence was observed in treatment with Cholorothalonil at 1.75% followed by cholorothanil at the 1.25%. However, the severity of the disease increased at the end of the growing period despite chemical treatments.

Table 14. Effects of fungicides on purple blotch and yield of onion at Bako (Getachew and Asfaw, 2000).

| Treatments | Rate (ha) | Disease score | Difference from check (%) | Mean yield (kg/ha) | Difference from check (%) |
|---|---|---|---|---|---|
| Unsprayed check | - | 44.56 (41.84$^{b}$) | - | 1630 | - |
| Cholorothalonil | 1.25 | 25.06 (29.82$^{d}$) | 28 | 2080 | 17 |
| Cholorothalonil | 1.75 | 19.56 (26.22$^{e}$) | 37 | 2170 | 33 |
| Cholorothalonil | 2.25 | 23.69 (29.17$^{d}$) | 30 | 1870 | 14 |
| Aspor 70% WP | 0.2 | 45.50 (45.83$^{a}$) | 9 | 1780 | 9 |
| Aspor 70% WP | 0.3 | 50.96 (40.68$^{bc}$) | 1 | 1680 | 3 |
| Aspor 70% WP | 0.4 | 25.31(30.17$^{d}$) | 27 | 1940 | 19 |
| Mean | | 35.52(34.71) | | 1880 | |
| C V | | (10) | | | |
| S E | | (1.75) | | | |

Values in parenthesis are transformed means.

## Control of basal rot

**Varieties:** Getachew and Asfaw (2000) reported that shallot varieties differ in their reaction to basal rot. Farmers also witnessed the presence of varietal differences among planting materials they used (materials from Hararghe were more susceptible than those collected from other areas). Screening of 58 shallot accessions against purple blotch in 2000 at Debere Zeit revealed only DTKT-1 to be resistant to the disease (Getachew and Asfaw, 2000). Among shallot

genotypes evaluated between 1993 and 1995 seasons, genotypes DZ-SHT-38 and DZ-SHT-58 were found to be susceptible to bulb rot, while DZ-SHT-61 was tolerant. Moreover, out of 77 genotypes evaluated for bulb rot nine of them showed less than 40% mortality (Table 15). This varietal difference indicates the potential to find resistant genotypes for management of the disease (Getachew and Asfaw, 2000).

Table 15. Reaction of shallot accessions to basal rot at Debre Zeit in 2002/2003 main season (Getachew and Asfaw, 2000).

| Accession | Basal rot severity (%) | Accession | Basal rot severity (%) | Accessions | basal rot severity (%) |
|---|---|---|---|---|---|
| DZ-SHT-38 | 19.2 | S2-24-89 | 67.2 | DZ-SHT-119 | 98.6 |
| DZ-SHT-OP-S14 | 23.2 | DTKT-27 | 68.2 | S1-29-89 | 98.6 |
| DZ-SHT-78 | 26.6 | DZ-SHT-OP-S9 | 68.7 | DZ-SHT-OP-S5 | 98.6 |
| DZ-SHT-61 | 28.9 | S1-17-89 | 68.9 | DZ-SHT-70 | 98.6 |
| DZ-SHT-140 | 32.5 | DZ-SHT-OP-S34 | 71.4 | DZ-SHT-S1-9-OP-89 | 98.6 |
| DZ-SHT-93 | 34.2 | S1-63-89 | 71.6 | DZ-SHT-50 | 98.6 |
| R-628-OP-S1 | 36.1 | Local | 72.4 | S1-30-89 | 98.6 |
| DZ-SHT-47 | 38.1 | DZ-SHT-17 | 76.5 | DZ-SHT--OP-S6 | 98.6 |
| S2-1-89 | 39.2 | DZ-SHT-56 | 78.6 | DZ-SHT-71 | 98.6 |
| DZ-SHT-25 | 40.2 | DZ-SHT-23 | 81.5 | Wolliso | 98.6 |
| S2-96-89 | 43.2 | DTKT-4 | 82.5 | DTKT-3 | 99.3 |
| DZ-SHT-162 | 49.2 | DZ-SHT-35 | 82.5 | DZ-SHT-OP-S25 | 100.0 |
| K-62 | 50.4 | DZ-SHT-25 | 83.3 | DZ-SHT-OP-S29 | 110.2 |
| DZ-SHT-OP-S2 | 51.7 | DZ-SHT-57 | 85.2 | DZ-SHT-11 | 117.2 |
| DZ-SHT-9 | 53.9 | BUKAR | 87.9 | R-618-OP-S1 | 117.2 |
| DZ-SHT-5 | 59.5 | DZ-SHT-OP-S3 | 90.9 | P-403-OP-S1 | 117.2 |
| DZ-SHT-91 (Huruta) | 59.3 | DZ-SHT-S3 | 91.1 | DZ-SHT-3 | 117.2 |
| DTKT-61 | 60.5 | DZ-SHT-63 | 91.9 | S2-OP-89 | 117.2 |
| S1-45-89 | 61.8 | DZ-SHT-81 | 98.6 | DTKT-39 | 117.2 |
| DTKT-1 | 62.9 | DZ-SHT-21 | 98.6 | DZ-SHT-2 | 117.2 |
| LSD 5% | 85.3 | | | | |
| S E | 531.4 | | | | |
| C V | 50.2 | | | | |

**Chemical control:** Nine registered seed dressing fungicides, namely Bayleton, Benlate, Vitvat, Beret 400 FS, Beret Special, Vincit, Prelude, Apron and Raxil with untreated control were evaluated for their efficacy on basal rot at Debre Zeit. Basal rot incidence and bulb yield were considered in evaluating

the effectiveness of the tested fungicides. No significant difference was observed between the fungicide treated and untreated plots both in reducing the basal rot incidence and in increasing bulb yield. However, Beret Special, Beret 400 FS and Prelude gave better protection. The highest bulb yield was obtained from Beret Special and Beret 400 FS treated plots while Bayleton treated plots gave the lowest yield (DZARC, 1994). In another report, among the nine tested seed dressing fungicides Beret Special (Fenpiclonil-imazalil) reduced the disease incidence by 160% and increased the bulb yield of shallot by 260% over the untreated check (Nigussie et al. 1993).

## Control of garlic rust (*Puccinia alli*)

**Varieties:** Evaluation of over 211 garlic germplasm revealed few entries (PB-220, PW-312, G-463, G-466) with less than 40% infection compared with the other entries tested. It was also observed that early maturing types succumbed to the disease much faster than the late maturing ones. The severity of rust was more pronounced on light soil than on black soil in the 1989 off-season.

**Chemical control:** Seven fungicides in 1989 and nine fungicides in 1991/92 seasons were evaluated against garlic rust at Debre Zeit and it was found that there was a significant difference between the fungicide treatments and the untreated check in rust severity, but the difference in bulb yield was not significant (Tables 16 and 17). However, Dithane M-45 gave relatively better yield than that of the other fungicides. Moreover, Bayfidan exhibited phytotoxicity on the crop. Further studies using the promising fungicides showed that weekly application of Alto (Cyroconazol), Anvil (Hexaconazole) or Tilt (Propiconazole 25%) considerably reduced rust severity (10-15%) as compared to the untreated check (72.5%) (DZARC, 1991; Seid and Mengistu, 1993). Weekly applications of Tilt and Alto reduced the disease better than biweekly applications (Seid and Mengistu, 1993).

Table 16. Mean fresh bulb yield and incidence of *F. oxysporium* of shallot cultivar DZSHT-78 treated with different fungicides in 1991/1992 at Debre Zeit (DZARC, 1994).

| Fungicides | Rate/ha | Incidence (%) | Bulb yield (q/ha) |
|---|---|---|---|
| Bayleton (Tridiaminol) | 107.0 g | 20.8 | 17.0 |
| Benlate (Benomyl) | 121.0 g | - | 24.13 |
| Vitavax (Carboxin) | 142.0 g | 11.9 | 20.34 |
| Beret 400 FS (Fenpiclonil) | 321.0 ml | 8.9 | 26.44 |
| Beret Special (Fenpiclonil) | 321.0 ml | 6.5 | 26.53 |
| Vincit (Flutriafol) | 121.0 ml | 12.8 | 21.56 |
| Prelude (Procloraz) | 107.0 g | 9.0 | 20.23 |
| Apron | 607.0 g | 10.1 | 22.88 |
| Raxil | 21.4 g | 12.2 | 24.69 |
| Control | - | 18.1 | 20.78 |
| LSD (0.05) | | NS | NS |
| CV | | 28.8 | 30.4 |

Table 17. Effect of some fungicides on garlic rust, and bulb yield of local garlic cultivar at Debre Zeit, 1989 (DZARC, 1991).

| Fungicides | Rate (kg/ha) | Garlic rust severity | Bulb weight (g) | Bulb yield (q/ha) |
|---|---|---|---|---|
| Bayfindan | 0.8 | 6.2 | 22.0 | 50.8 |
| Calyxin | 3.0 | 9.1 | 26.9 | 55.5 |
| Tilt | 0.5 | 7.0 | 25.4 | 53.9 |
| Alto | 0.8 | 8.2 | 26.9 | 55.5 |
| Impact | 1.0 | 12.4 | 27.0 | 52.3 |
| Anvil | 0.8 | 7.5 | 28.8 | 58.0 |
| Dithane M-45 | 16.9 | 6.7 | 27.9 | 80.5 |
| Control | - | 83.2 | 23.9 | 55.5 |

## White rot of garlic

The management of white rot (*Sclerotium cepivorum*) is very difficult due to its persistence for more than 40 years in the soil. A varietal screening study showed that P-302 and G-415 were tolerant to white rot compared to G-493 (Table 18).

Table 18. Reaction of different garlic cultivars to white rot at three locations in 2000 main season **(**after DZARC, 2000).

| Cultivars | White rot (%) | | | | Mean |
|---|---|---|---|---|---|
| | DZ vertisol | DZ light soil | Akaki | Huruta | |
| W-003 | 30.63 | 65.87 | 7.30 | 33.30 | 34.28 |
| W-013 | 33.93 | 67.23 | 8.54 | 50.33 | 40.01 |
| W-014 | 36.53 | 36.43 | 8.47 | 42.70 | 31.03 |
| W-017 | 44.4 | 55.73 | 7.07 | 38.60 | 36.45 |
| R-102 | 40.17 | 56.63 | 8.23 | 68.07 | 43.28 |
| PB-203 | 28.87 | 53.17 | 3.90 | 31.93 | 29.47 |
| PB-204 | 24.03 | 58.03 | 3.62 | 39.90 | 31.40 |
| PB-206 | 67.33 | 56.60 | 7.97 | 58.93 | 47.71 |
| PB-207 | 63.33 | 56.20 | 3.85 | 48.53 | 42.98 |
| PB-223 | 54.47 | 53.77 | 4.37 | 40.27 | 38.22 |
| P-302 | 24.07 | 32.73 | 2.12 | 26.47 | 21.35 |
| G-404 | 45.97 | 53.07 | 4.67 | 49.80 | 38.38 |
| G-412 | 53.73 | 47.43 | 4.27 | 49.20 | 38.66 |
| G-415 | 25.37 | 37.53 | 3.00 | 30.37 | 24.07 |
| G-420 | 39.40 | 72.53 | 11.35 | 49.70 | 43.25 |
| G-428 | 56.30 | 57.03 | 7.73 | 40.37 | 40.36 |
| G-459 | 57.00 | 51.40 | 7.17 | 58.57 | 43.54 |
| G-493 (Tsedey) | 85.23 | 75.93 | 17.37 | 81.70 | 65.06 |
| P-502 | 47.97 | 57.03 | 5.53 | 57.07 | 41.90 |
| Mean | 45.19 | 54.97 | 6.66 | 47.15 | 38.49 |
| $LSD_{0.05}$ | 23.77 (15.36) | 23.00 (15.05) | 7.85 (9.08) | 13.06 (7.82) | |
| CV | 22.05 | 18.81 | 39.7 | 10.90 | |

LSD values in parenthèses are Arcsin transformations.

## Downy mildew

This is one of the most common and problematic diseases of Allium species particularly shallot and onion. It is highly favored by cool and humid weather.

**Varieties:** Four shallot genotypes (DTKT 61, DTKT 35, BUKAR, and DTKT 27) showed less disease severity compared to the other materials tested indicating a potential to find tolerant varieties for the management of the disease (Table 19) (DZARC, 2003).

Table 19. Reaction of different shallot accessions to downy mildew (after DZARC, 2000).

| Accession | Severity (%) | Accession | Severity (%) | Accession | Severity (%) |
|---|---|---|---|---|---|
| DTKT-61 | 11.7 | DZ-SHT-75 | 35.0 | S2-OP-89 | 46.7 |
| DTKT-35 | 16.7 | Z-SHT-47 | 35.0 | P-403-OP-S25 | 46.7 |
| BUKAR | 16.7 | DZ-SHT-93 | 35.0 | DZ-SHT-OP-S5 | 48.3 |
| DTKT-27 | 18.3 | DZ-SHT-S19-OP-89 | 35.0 | DTKT-3 | 48.3 |
| DZ-SHT-50 | 20.0 | DZ-SHT-57 | 35.0 | DZ-SHT-56 | 50.0 |
| S1-29-89 | 21.7 | DZ-SHT-71 | 35.0 | S2-1-89 | 53.3 |
| DZ-SHT-OP-S6 | 23.3 | DZ-SHT-61 | 35.0 | DZ-SHT-OP-S34 | 53.3 |
| DZ-SHT-81 | 25.0 | DZ-SHT-17 | 36.7 | DZ-SHT-OP-S2 | 53.3 |
| DTKT-4 | 26.7 | DZ-SHT-2 | 36.7 | S1-63-89 | 56.7 |
| K-62 | 26.7 | S2-24-89 | 38.3 | DZ-SHT-3 | 56.7 |
| DTKT-1 | 26.7 | P-403-OP-S1 | 40.0 | DZ-SHT-23 | 60.0 |
| DTKT-39 | 26.7 | DZ-SHT-5 | 41.7 | DZ-SHT-OP-S9 | 63.3 |
| DZ-SHT-OP-S14 | 28.3 | DZ-SHT-63 | 41.7 | S1-45-89 | 63.3 |
| DZ-SHT-70 | 30.0 | Wolliso | 43.3 | R-618-OP- S1 | 63.3 |
| DZ-SHT-38 | 30.0 | R-621-OP-S1 | 43.3 | S1-17-89 | 63.3 |
| DZ-SHT-25 | 30.0 | Local | 43.3 | DZ-SHT-OP-S3 | 63.3 |
| DZ-SHT-9 | 30.0 | DZ-SHT-140 | 45.0 | S3-96-89 | 66.7 |
| DZ-SHT-11 | 31.7 | DZ-SHT-21 | 45.0 | DZ-SHT-OP-S29 | 73.3 |
| DZ-SHT-68 | 33.3 | DZ-SHT-78 | 45.0 | DZ-SHT-162 | 73.3 |
| DZ-SHT-91 (Huruta) | 35.0 | S1-30-89 | 46.7 | - | - |
| $LSD_{0.05}$ | 24.7 | | | | |
| CV | 24.6 | | | | |
| SE | 141.7 | | | | |

**Fungicides:** Mancozeb 80% WP, Ridomil MZ 63.5 and Ridomil gold have been in use to control the disease, but in the last two seasons, these fungicides have neither protective nor curative effect on the disease at Debre Zeit Research Center and at Alemaya University.

## Plant parasitic nematodes

Fifty eight tomato cultivars and lines were screened against the root-knot nematode *M. incognita* in the greenhouse, and it was found that seven of the materials were resistant, 11 moderately resistant, 28 moderately susceptible and 12 susceptible, while the remaining two were highly susceptible. The

resistant lines were checked in the field under high nematode pressure and were forwarded to the improvement program (PPRC, 1998; 2000).

The potential of organic amendments; manure, straw, mixture of manure and straw and noug cake were evaluated for the control of root-knot nematode on tomato, and results showed that noug cake significantly reduced damage of roots by nematode compared with the other amendments tested. Manure has positively increased plant performance without significant nematode reduction. Hence, potential use of these and other amendments wherever applicable are recommended to be tested on larger plots (PPRC, 1998; 2000).

### Viruses

Attempts were made to screen pepper and tomato genotypes for resistance to the predominant isolates of Ethiopian potyviruses (Yaynu, 1998). A range of pepper and tomato breeding lines which had previously been tested in the Asian Vegetables Research and Development Center (AVRDC) were also included. The Ethiopian potyvirus isolates from pepper, in particular isolate 430/94 and EPMV-PN1 caused severe symptoms on most of the breeding lines compared with the reference potyviruses CVMV and PVMV. Several of the CVMV resistant genotypes from AVRDC were susceptible to the Ethiopian isolates. Serano Vera Cruz was immune and Agronomico 8 was either immune to or only latently infected with all the Ethiopian isolates tested indicating that they could serve as sources of resistance for breeding (Yaynu, 1998; Yaynu and Vetten, 2000). Tamiru (2004) also found that pepper genotypes PBC 972, PBC559, PBC 223, and Bako local were resistant to EPMV.

## Conclusion and recommendations

The vast majority of vegetable production in Ethiopia is dominated by smallholders that do not have access to improved and effective pest management technologies. Efforts to transfer crop protection technologies generated through research were minimal due to poor research-extension-farmers linkage (Kindu et al., 2004). Non-pesticide management options such as cultural and host resistance against major pests did not reach the smallholder vegetable farmers due to limited effort made by the research-extension system (Mohammed et al., 2006).

Damping off on tomato and pepper seedlings can be effectively controlled by solarization of seedbeds using black polythene sheets for 20-30 days during sunny months in the Rift Valley where the mean temperature is relatively higher. Burning a layer of maize/sorghum stalks on the seedbed, and dressing

of tomato and pepper seeds with fungicides such as Apron star effectively reduced damping off infection. Field application of Ridomil gold 68% WP, Mancolaxyl and Fungomil at 350, 250, 250 gm/100 liter of water, respectively, reduced late blight infection and increased marketable yield of tomato. Alternate application of Mancozeb and Ridomil gold reduced purple blotch severity and increased bulb yield of onion.

Studies on root-knot nematodes focused mainly on generating baseline information rather than management options. Future studies should concentrate on generation of knowledge and technologies that can be used for effective management of these nematodes. There are few success stories of using resistant cultivars in the world. The high probabilities of finding mixed infection by the three species make this option less practical. Thus, cultural practices including the use of crop rotation, fallowing, desiccation, eradication of alternate hosts etc. need to be investigated. In addition, nematicides for treatment of planting materials and seedbed need to be evaluated both for efficacy and economic return. While focusing on root-knot nematodes, work should continue on other species which are potentially damaging ones like *Pratylenchus* spp. (lesion nematodes), *Helicotylenchus* spp. (sting nematode), *Heterodera* spp. (cyst nematodes) etc.

Viruses infecting pepper and tomato were studied extensively in the last 10 years. Potyviruses are among the major diseases constraining pepper production. In tomato, yellow leaf curl has recently witnessed to be the major constraint some time reaching 100% incidence in some large scale farms. Studies on the management of these viruses by various means should be given high priority.

## Gaps and challenges

Research on vegetable disease management is still not satisfactory. Vegetables are highly vulnerable to various diseases and thus there is a need to devise safe, effective and sustainable disease management methods. The bulk of research activities conducted on vegetable disease management so far dealt with pesticide chemicals. It is well known that repeated use of synthetic pesticides alone may create resistance within population of various pathogens. Moreover, since vegetables are frequently treated with pesticides, there is a greater likelihood of direct human exposure and pesticide residue on fresh vegetables thereby adversely affecting both domestic and export vegetable market.

Review of research on vegetable crop diseases in the last two decades clearly shown that there are critical research gaps to be filled. The situation will be more serious in the future as irrigated agriculture increases. CSA (2003)

reported that in the past five years alone, every year there has been an average of 10% increase in irrigated land. It is believed that year round cultivation of vegetables in the central Rift Valley for the last decades created conducive environment for buildup of various diseases.

Downy mildew on shallot has become a major problem around Debre Zeit and Alemaya. Application of Ridomil and Mancozeb could not control the disease. Therefore, alternative fungicides and other control options should be worked out in the near future. Moreover, care should be given to avoid build up of resistant races/patho-types to these commonly used fungicides.

Bulb rot and white rot are major constraints of shallot and garlic production. Little effort has been made so far to develop control options. Strict measures should be taken to avoid dissemination into non-infected areas through infected bulbs.

Although nematodes had been reported as one of the serious production constraints of vegetables during the 1985 symposium (Tesfaye and Habtu, 1985), minimum effort has been made in terms of human resource and facility development in the past 20 years. The establishment of the Nematology Research Unit at Melkassa Agricultural Research Center was in response to this need in the rift valley but it was not strengthened due to lack of material and financial support. This has to be changed in order to generate research technologies and knowledge, and more work has to be done on the problems of irrigated agriculture nationwide. Currently, the available yield loss data on vegetable crops is scanty, although in crops like tomato a loss of more than 70% was recorded in some instances due to root-knot nematodes (Wondirad Mandefro, personal observation). Similarly, yield losses incurred by viruses were not quantified. Management options against the predominant and widespread viruses have also not been developed. Thus, research gaps that need to be addressed in the near future are yield loss studies due to individual and/or mixed virus infections, vector-reservoir host relationship studies and status of newly emerging or shifting diseases and their management.

The majority of smallholder vegetable farmers are not able to differentiate vegetable diseases mainly due to lack of technical know-how and awareness. As a result, smallholder vegetable farmers apply pesticides haphazardly without using the appropriate rate and frequency of application and safety measures. Such misuse of pesticides could adversely affect growers, consumers and the environment in general.

## Future

Vegetable production is expanding year after year in the Central Rift Valley and in areas with similar climatic conditions throughout the country due to the use of irrigation. The area coverage of vegetables was estimated to be about 129, 200 ha without considering the home gardens (Lemma et al., 1994). As the demand for vegetables both in the local and export markets is increasing from time to time, production is expanding in area over seasons. Vegetable seed production of mainly onion and tomato has become an attractive business enterprise in many parts of the country. Growing of vegetables throughout the year has created conducive conditions for the buildup of many diseases demanding comprehensive research outputs for their effective and sustainable management.

Future research should focus on developing an IPM with no or minimum input of chemical pesticides. The country being strategically linked to the European and Gulf markets, all exportable produce has to qualify with stringent criteria including EUREP GAP (Europe Good Agricultural Practice). Thus, researchers have to consider these opportunities while developing research agenda.

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# Review of Research on Fruit Crop Diseases in Ethiopia

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## Introduction

Fruits are the most important crops grown at various agro-ecologies of Ethiopia by both small holders, private commercial farmers and state owned large-scale farms. The very diverse agro-ecologies of the country are conducive to grow various tropical, subtropical, and temperate fruits. The total area coverage of different fruit crops in small holding peasants alone is about 45205 ha (CSA, 2004). This figure does not include the area of pineapple and apple, which are still expanding in the highlands of Ethiopia. The area coverage of fruits under commercial farms is estimated to be about 5800 ha (Seifu, 2004). From these figures, it can be noted that the bulk area coverage of fruits is still under smallholder farmers. Fruits widely grown in Ethiopia include citrus (orange, mandarine, lemon lime, and grape fruit), banana, papaya, grapevine, pineapple, tropical, and sub-tropical fruits like mango, avocado, guava, and some other deciduous fruits such as peach, apple, and plum (Herath *et al*., 1994; Edossa, 1998). The most important fruit crops grown by smallholder farmers are presented in Table 1.

Table 1. Area and production of fruit crops by private peasant holdings in Ethiopia.

| Type of fruits | Area (ha) | Percentage share of the area | Production (q) | Percentage share of production |
|---|---|---|---|---|
| Avocado | 2918.51 | 7.94 | 147159.79 | 7.21 |
| Banana | 21937.59 | 59.65 | 1245615.6 | 61.01 |
| Guava | 1426.38 | 3.88 | 19399.76 | 0.95 |
| Lemon | 796.28 | 2.16 | 12021.39 | 0.59 |
| Mango | 3989.06 | 10.85 | 212750.25 | 10.42 |
| Orange | 2558.95 | 6.99 | 154624.72 | 7.57 |
| Papaya | 2981.41 | 8.11 | 246890.1 | 12.0 |
| Pineapple | 171.24 | 0.47 | - | - |

Source: CSA, 2004.

The production and productivity of fruit crops in Ethiopia is seriously affected by different constraints among which diseases are the major ones. Fruits are attacked by a number of diseases caused by fungi, bacteria, viruses, viroid, nematode, and phytoplasma. Many of the commercial fruit farms and smallholder fruit orchards are declining mainly due to disease problems (Mohammed, 2002; Seifu, 2004). Research on diseases of fruits was very negligible and focused mainly on surveys and identification of the causal pathogens. The available research information on fruit pathology were reviewed and documented by different authors (Tesfaye and Habtu, 1985; Godfrey-Sam-Aggrey, 1987; Zimmermann, 1987; Lemma, 1994). During the past twenty years, attempts were also made to identify and characterize new and potential fruit diseases, and to device management practices against the major ones. This paper tries to collate these findings, identify gaps, and suggest future directions.

# Research findings

## Diseases recorded

Exhaustive list of plant pathogens associated with various fruit crops in Ethiopia were reported in the previous reviews (Tesfay and Habtu, 1985; Lemma, 1994). In recent years, several other plant pathogens have also been positively identified as a potential threat to the production of different fruit crops. Of these, leaf and fruit spots of citrus (*Phaeoramularia angolensis*), citrus anthracnose (*Colletotrichum gloeosporioides*), citrus canker (*Xanthomonas axonopodis pv. citri*), root rot/decline on avocado (*Phytophthora cinnamomi*), black spot of papaya (*Asperisporium caricae*), papaya anthracnose (*Colletotrichum gloeosporioides*), dieback of papaya caused by phytoplasma, mango anthracnose (*Colletotrichum gloeosporioides*) and papaya ring spot virus were reported to be the most important (Table 2). In the past Phaeoramluaria leaf and fruit spots of citrus were known to be restricted in the south and southwest Ethiopia (Eshetu, 1999). However, now the disease is widespread to the northwest of the country (Fig. 1), causing heavy decline in many citrus orchards (Yigzaw and Gelelbelu, 2002; Mohammed, 2007). Fruits infected with this disease become extremely hard, unattractive, and juiceless. In the eastern part of Ethiopia, anthracnose was reported to be the major pre-harvest disease of citrus followed by Alternaria fruit spot and fruit blemishes. In addition, fungi like *Colletotrichum* and *Alternaria* species were also found to be associated with citrus leaves during non-fruiting seasons., while *penicillium* rot was a major post-harvest rot of citrus (Temam *et al*., unpublished).

Table 2. Major fruit diseases and their status.

| Host | Common name | Scientific name | Status | Ref. |
|---|---|---|---|---|
| Citrus | Phaeoramularia leaf and fruit spot | *Phaeoramularia angolensis* | Major | 10 |
| | Anthracnose | *Colletotrichum gloeosporioides* | Major | 3 |
| | Dieback | Phytoplasma | Minor | * |
| | Fruit rot | *Penicillium italicum* | Major | * |
| | | *Aspergillus niger* | Moderate | * |
| | Leaf spot | *Alternaria citri* | Moderate | * |
| | Canker | *Xanthomonas axonopodis pv. citri* | Moderate | 12, 13 |
| | Wilt | *Fusarium oxysporum* | Minor | 24 |
| | Exocortis | Viroid | Moderate | 24 |
| Banana | Wilt | *Xanthomonas campestris pv. musacearum* | Major | * |
| | Anthracnose | *Colletotrichum musanum* | Minor | 24 |
| | Leaf spot | *Mycosphaerella musicola* | Minor | 24 |
| | Nematodes | *Helicotylenchus multicinctus* | | * |
| | | *Rotylenchulus anamictus* | | * |
| | | *Helicotylenchus* sp. | | * |
| | | *Melodogyne sp.* | | * |
| Mango | Anthracnose | *Colletotrichum gloeosporioides* | Major | 3 |
| | Root rot | *Phytophthora sp.* | Minor | 3 |
| Avocado | Root rot/decline | *Phytophthora cinnamomi* | Major | * |
| | Wilt | *Verticillium* sp. | Minor | * |
| | Anthracnose | *Colletotrichum gloeosporioides* | Major | * |
| Papaya | Anthracnose | *Colletotrichum gloeosporioides* | Major | 3 |
| | Black spot | *Asperisporium caricae* | Major | 3 |
| | Papaya ring spot virus | potyvirus | Moderate | * |
| | Dieback | Phytoplasma | Major | * |
| Apple | Scab | *Venturia inequalis* | Major | 15, 24 |
| | Crown and root rot | *Phytophthora* spp. | Major | 24 |
| | Crown gall | *Agrobacterium tumefaciens* | Major | 24 |
| | Powdery mildew | *Podosphaera leucotricha* | Major | 15 |

* Positively identified but data not published.

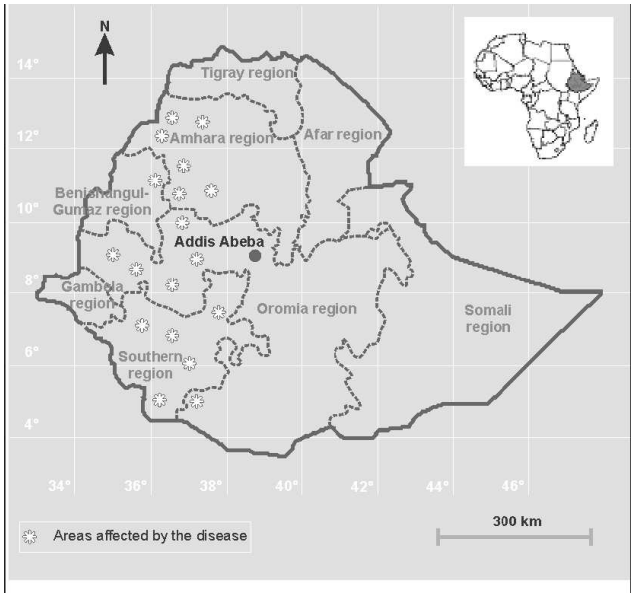


Fig. 1. Geographic distribution of phaeoramularia leaf and fruit spots of citrus (after Mohammed, 2007).

Studies on *Xanthomonas axonopodis pv. citri* indicated that the disease was widespread in the Rift Valley attacking Mexican lime (*Citrus aurantifolia*) and sour orange (*Citrus aurantium*) (Table 3). The occurrence of citrus canker was reported since early 1980s; however, it was not confirmed until now. The host range being limited to Mexican lime and sour orange makes it similar to *Xac* - A* atypical Asiatic (Eshetu *et al*., 2007). Diagnostic surveys conducted on banana in the major banana growing areas of the country revealed seven nematode species (Table 4). Except in Tepi and Shewarobit, the nematode species recorded were similar in all of the areas surveyed. The predominant nematodes were *Radopholus similis, Helicotylenchus multicinctus,* and *Meloidogyne* sp. The lesion nematode *Pratylenchus goodey*i was the only nematode found in association with banana in Tepi. This nematode was reported on enset in Ethiopia and on many other crops worldwide (Wondirad *et al*, unpublished). The association of the different species to the observed root damage was difficult to establish. The maximum root necrosis index of 44.84 was found at Shele in Arbaminch on mother plants, and the minimum was 8.4 on suckers at Merti Jeju. Root necrosis index is one of the important indicators of nematode damage to the root system, although it depends on the number of dead and healthy roots and seasons.

Table 3. Incidence and severity of canker on citrus (Mexican lime) leaves in the central Rift Valley of Ethiopia (2004) (after Eshetu and Kamaruzaman, 2007).

| Location | Crop age (years) | Incidence (%)[1] | Mean range[2] | Severity (%) | Mean range[2] |
|---|---|---|---|---|---|
| Awara Melka | 15 | 84 a | 70 - 90 | 35.9 a | 26.0 - 44.2 |
| Melka Werer | 3 | 65 b | 60 - 70 | 25.6 c | 11.9 - 34.4 |
| Merti Jeju | 10 | 71 ab | 35 - 90 | 30.3 b | 25.0 - 38.65 |
| Merti Jeju | 10 | 63 b | 55 - 65 | 17.3 d | 12.7 - 23.0 |
| Nura Era | 1 | 74 ab | 60 - 80 | 24.8 bc | 16.7 - 34.9 |
| Mean | - | 71.4 | - | 26.78 | - |
| C. V | - | 11.65 | - | 25.76 | - |
| S. E. M. | - | 3.72 | - | 3.08 | - |

Means within a column followed by the same letter(s) are not statistically different at $P \leq 0.05$ (Tukey test). [1] % of leaves with at least one lesion, [2] mean of five trees.

Table 4. Banana farms with root necrosis index of roots of mother plant and sucker and nematode species identified from different agro-ecologies.

| Sites | Banana variety | No. of farms | Average RNI* | | Nematode species |
|---|---|---|---|---|---|
| | | | Mother | Sucker | |
| Melkasedi | Poyo | 5 | 21.24 | 12.16 | *Radopholus similis*, *Helicotylenchus multicinctus*, *Helicotylenchus* sp., *Meloidogyne* sp., *Rotylenchulus anamictus* |
| Awaramelka | Dwarf Cavendish | 5 | 19.92 | 21.12 | *Radopholus similis*, *Helicotylenchus*, *Meloidogyne*, *Rotylenchulus* spp. |
| Nuraera | Dwarf Cavendish | 1 | 25.2 | 17.6 | *Helicotylenchus multicinctus* |
| Mertijeju | Dwarf Cavendish | 1 | 12.8 | 8.4 | *Helicotylenchus multicinctus*, *Meloidogyne* sp. |
| Arbaminch | Dwarf Cavendish | 5 | 36.92 | 26.72 | *Radopholus similis*, *Helicotylenchus multicinctus*, *Helicotylenchus*, *Meloidogyne* spp. |
| Shele | Ambo wuha | 5 | 44.84 | 27 | *Radopholus similis*, *Helicotylenchus multicinctus*, *Helicotylenchus*, *Meloidogyne*, *Aphelenchoides* spp. |
| Tepi | Kenya | 5 | 27.44 | 9.96 | *Pratylenchus goodeyi*, *Pratylenchus* sp. |
| Shewarobit | Dwarf Cavendish | 5 | 36.86 | 16.8 | *H. multicinctus*, *Meloidogyne* sp., |

*RNI= Root necrosis index

Banana is a natural host of enset wilt pathogen *Xanthomonas campestris pv. musacearum* (*X. cm*) (Dagnachew, 1968). In 1974, epidemics of bacterial wilt in banana cv. Ducasse hybrid were reported in Kaffa region, southwestern part of

Ethiopia (Dagnachew and Bradury, 1974). More recently, several banana plants infected by the wilt pathogen have been observed in enset plantations at Sidama, Gedeo, Wolayita, Kembata, and Hadya zones (Quimio and Mesfin, 1991; 1992).

Avocado root rot or decline caused by *Phytophthora cinnamomi* was observed in avocado orchards in the early 1990s at the Jimma Research Centre (JARC). Surveys conducted since then confirmed that avocado root rot is widely distributed in all districts of Jimma, Illubabor and Wellega zones causing heavy crop damage. For instance at JARC three to five large avocado orchards consisting of around 100-200 very productive trees were destroyed by the disease between 1990 and 2005 (Table 5). The disease is quite common on young trees, and most severely magnified on older fruit bearing trees causing extensive root damage. The root rot or decline of avocado trees has become a major production problem to growers in most parts of southwestern regions. The disease is widespread in all districts of Jimma causing severe decline of avocado trees (Table 6).

A systematic survey of temperate fruits conducted during the 2005/06 crop seasons in nine major growing areas of Gamo Goffa, Gurage, Sidama, Hadiya and Siltie zones of the southern region indicated that apple scab, powdery mildew and leaf curl (on peach and cherry plum) were predominant at all locations causing heavy losses on temperate fruits in this region (Fikre, 2006).

Table 5. Status of avocado root rot/decline in various fields sampled at the Jimma Research Center.

| Sample field | Planting year | No. of healthy trees | No. of infected dead trees | Incidence (%) |
|---|---|---|---|---|
| Horticulture | 1978 | 0 | 100 | 100.0 |
| National Collection | 1987 | 199 | 31 | 14.0 |
| Agronomy | 1989 | 13 | 167 | 92.8 |
| Semeno | 1990 | 155 | 66 | 29.9 |
| Grafted * | 1992 | 18 | 12 | 40.0 |
| Total | | 385 | 376 | 49.4 |

* Different accessions of grafted and transplanted avocado trees in the field.

Table 6. Incidence of avocado root rot (decline) in farmer's orchards in different districts of Jimma Zones.

| District | Kebele | No. of sample orchards | Incidence (%) |
|---|---|---|---|
| Seka | Meti | 2 | 20.8 |
| | Atero Gafesa | 4 | 18.2 |
| | Shashamene | 2 | 20.0 |
| | Gibe Bosso | 2 | 6.6 |
| | Boyo Kechema | 4 | 9.6 |
| | Kofe | 8 | 18.5 |
| | Sub total | 22 | 15.6 |
| Kersa | Tikur Balto | 5 | 33.3 |
| | Babo Sarte | 3 | 11.6 |
| | Merewa | 3 | 20.0 |
| | Bedabuna | 3 | 15.6 |
| | Sub total | 14 | 20.1 |
| Manna | Dewa | 3 | 20.0 |
| | Haro | 2 | 0.0 |
| | Bilida | 4 | 1.3 |
| | Somodo | 7 | 12.0 |
| | Eladale | 4 | 17.6 |
| | Doyotoli | 5 | 20.6 |
| | Doyobikila | 6 | 27.4 |
| | Sub total | 31 | 14.1 |
| | Total | 67 | |

Source: Girma, unpublished data.

# Basic studies

## Pathogenicity test

Studies conducted to determine the causal agent of citrus anthracnose in the Upper Awash farms confirmed that *Colletotrichum gloeosporioides* was the causal agent of the disease on citrus (Girma, unpublished). Eshetu (1999) confirmed that the causal agent of leaf and fruit spots of citrus was *Phaeoramularia angolensis*. Eight representative *X. axonopodis pv citri* isolates obtained from leaves showing canker symptoms at Awara Melka, Melka Werer, Merti Jeju and Nura Era were evaluated for their pathogenicity using detached leaf assay technique on sour orange (*Citrus aurantium*), pomelo (*C. grandis*), Mexican lime *C. aurantifolia*), calamondin (*C. madurensis*), sweet orange (*C. sinensis*) and grapefruit (*C. paradisi*), and it was reported that *X. axonopodis* pv. *citri* isolates were consistently recovered from inoculated leaves of the Mexican lime and sour orange, but not from the other citrus species. All of the eight isolates were pathogenic to the Mexican lime and sour orange, and

the isolates did not differ from each other in pathogenicity suggesting that they were probably from the same population (Eshetu and Kamaruzaman 2007).

## Characterization of pathogens

*Xanthomonas axonopodis* pv. *citri* isolates collected from diseased leaves of Mexican Lime (*Citrus aurantifolia*), and sour orange (*Citrus aurantium*) in the Rift Valley were characterized on the basis of their cultural, biochemical, physiological and metabolic properties following standard determinative tests. In the cultural characterization, yellow, domed, mucoid colonies indicative of *Xanthomonas* were isolated after 48 hr of incubation at 30 °C on yeast dextrose chalk agar (YDCA). The yellow pigment consisted of a unique family of brominated aryl octanes, which is called xanthomonadins, and is characteristic of the genus *Xanthomonas.* In the biochemical and physiological characterization, all of the eight isolates showed similar reactions to the standard determinative tests; they were negative to the nitrate reduction, methyl red test, fermentative growth test and oxidase reaction, while they showed positive reactions to the rest of the tests.

In order to determine the species complex and/or strains of *Colletotricum* responsible for the papaya anthracnose in Ethiopia, 24 isolates from papaya in the Central Rift Valley (Ziway/ Ethio-Flora, Meki, Melkassa and Bishola) were sent to Volcani Center in Israel for further molecular characterization. Of the 24 isolates, nine collected from Meki and Melkassa were proved *Colletotrichum gloeosporioides* using species-specific primers. No amplified fragments were detected using *Colletotrichum acutatum* specific primers for any of the cultures, indicating that this species was not present in the locations sampled. The other 15 isolates collected from Bisholla, Abernossa, and Ziway were amplified using primer Coll, previously identified at Volcani Center by the group of Freeman, which amplified a population of *Colletotrichum* belonging to a unique species mainly attacking passiflora fruits in Colombia. This indicates that the anthracnose pathogen population affecting papaya in Ethiopia is diverse and perhaps the sexual stage exists thereby contributing to its genetic variability (Freeman and Dereje, 2004).

A new papaya disease was recently observed in many papaya growing areas of the Central Rift Valley. The disease started by yellowing the upper young leaves and progressed downward causing a total crop failure. Samples collected from diseased and healthy looking papaya plants, and sent to the Rothampsted Research Center in UK for molecular identification showed that all the symptomatic papaya samples were positive to Phytoplasma, and all healthy looking samples remained negative. Samples collected from orange trees that

showed decline symptom at Melkassa, and three other weed species from papaya fields were also found positive to phytoplasma using PCR analysis. The identified phytoplasma was further sequenced at the Dundee University in Scotland and the results indicated that the 16S rDNA of the phytoplasma identified from papaya has 98% homology with that of yellow crinkle in Australia, accession Number Y 10097 in Gene bank NCBI, which belongs to group 16SrII peanut wiche's broom. Results of sequence analysis on samples of sweet orange (*Citrus sinensis*) and three weed species, *Recinus communi*, *Galinsoga parviflora* and *Parthenium histrophorus* collected from the nearby papaya fields were also similar with that of papaya samples (Birhanu, *et.al*, unpublished).

## Phaeoramularia leaf and fruit spots of citrus

Infected leaves, fruits, and twigs served as sources of inoculum for *Phaeoramularia angolensis* in citrus orchards. More lesions were counted on both leaves and fruits during the wet and humid seasons than in the dry seasons. Sporulation of the fungus was also very high on young leaves and fruits. The number and size of lesions were also higher and larger around the lower tree canopy than in the middle and upper canopy (Mohammed, 2002; Kassahun *et al*., 2006). The susceptibility of both leaves and fruits of citrus decreased as their age increased. Fruits could be attacked by the disease at all developmental stages, while; older leaves were more resistant as compared to young leaves. Extended and high rainfall during the months of August and September created favorable conditions for infection of leaves and fruits at Ghibe. *P. angolensis* was more severe on fruits than leaves of sweet orange in different citrus growing areas of Jimma. (Fig. 2). The percentage of premature leaf defoliation of sweet orange was significantly and positively correlated ($R^2 = 0.95$) with the severity of *P. angolensis* at Chagni, north-west Ethiopia (Fig. 3). Evaluation of different citrus species in a hot spot area for their relative susceptibility to *P. angolensis* based on incidence and severity assessment indicated that grapefruit (*Citrus paradisi*) was the most susceptible followed by sweet orange (*C. sinensis*). Mandarine (*C. reticulata*), lemon (*C. limon*) and lime (*C. aurantifolia*) were found to be less susceptible.

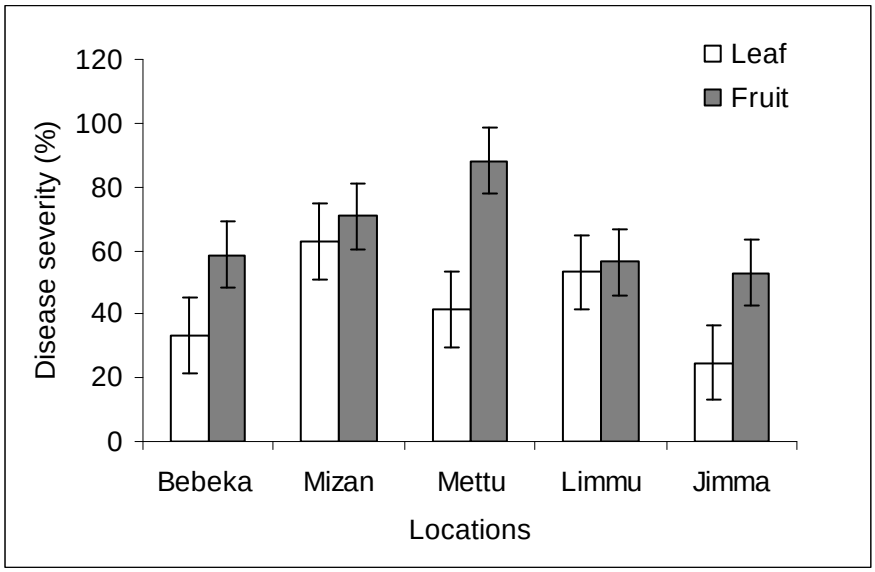


Fig. 2. Severity of phaeoramularia leaf and fruit spots on sweet orange in southwest Ethiopia. (after Eshetu, 1997).

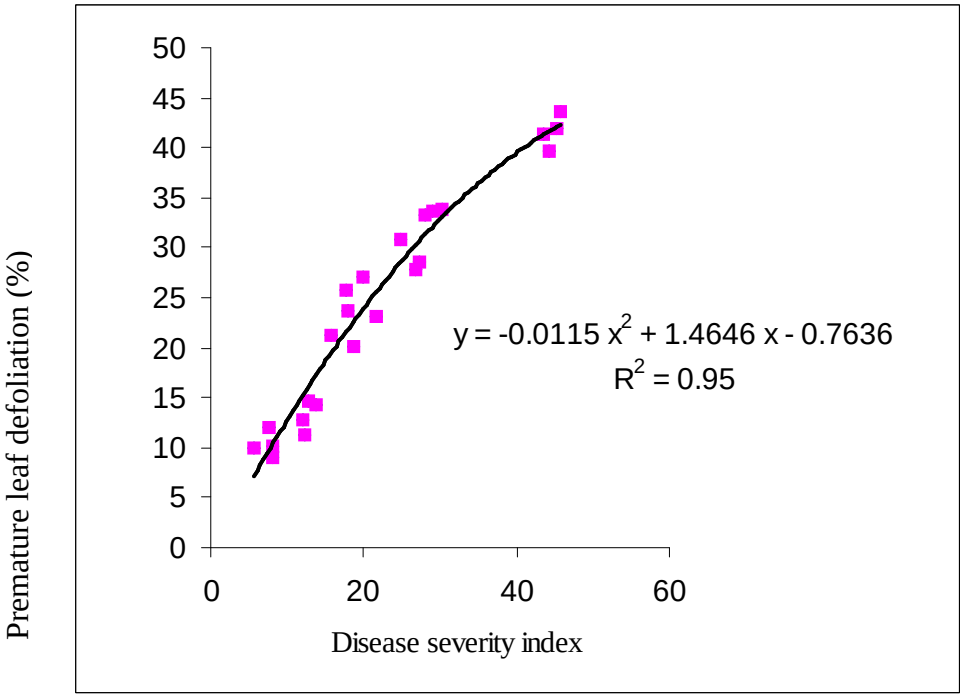


Fig. 3. Relationship between disease severity index and premature leaf defoliation due to leaf and fruit spots of citrus at Chagni (after Kassahun et al., 2006).

### Indexing virus and virus-like diseases of citrus

The presence of citrus tristeza virus in Ethiopia was reported only based on field and indicator plant symptoms. However, recently tristeza virus was positively detected from sweet orange samples collected from the Upper Awash citrus orchard using serological test (Birhanu, unpublished). Different grafting techniques (leaf patch, bark patch and leaf disc) were used for citrus indexing. Among the tested grafting techniques, only leaf-patch and bark-patch were successful. Diagnostic symptoms of greening, psorosis-A, concave gum, blind pocket, wrinkled leaves and seedling yellows were observed. Symptoms typical of tristeza and exocortis were also noted. Moreover, a strong indication of greening psorosis and exocortis was observed using indicator plant test (Van Bruggen and Almaz, 1985). Attempts were made to index and produce disease free planting materials of citrus using indicator plant test at Melkassa. Accordingly, periodic re-indexing of foundation block was done mainly for tristeza, exocortis and psorosis. Encouraging results were obtained on virus indicator and virus free foundation blocks. Over 90% establishment was achieved on virus indicator foundation blocks (IAR, 1987).

# Disease management

## Cultural control

### Phaeoramularia leaf and fruit spots of citrus

Sanitation measures such as timely removal of infected fruits, twigs and leaves reduced the incidence and severity of leaf and fruit spots of citrus (*Phaeoramularia angolensis*). Moreover, timely pruning, proper water management, and optimum fertilization were also recommended for the management of the disease in south-west Ethiopia. These practices were reported to reduce the buildup of inoculum at the Ghibe citrus orchard (Million, pers. com.).

### Papaya anthracnose

Studies conducted on time of removing infected plant parts on disease control at Tibila farm showed that removal of infected plant parts every two weeks significantly reduced the buildup of papaya anthracnose (*Colletotrichum gloeosporioides*) indicating that sanitation measures are important components of integrated disease management strategy against papaya anthracnose (MARC, 2001).

# Host-plant resistance

## Phaeoramularia leaf and fruit spots of citrus

Five sweet orange varieties (Washington Navel, Pineapple, Hamlin, Campbell Valencia and Jaffa) evaluated for their reaction to Phaeoramularia leaf and fruit spots of citrus at Chagni (Table 7) showed that Jaffa and Campbell Valencia were moderately resistant as compared to the other varieties tested (Kassahun *et al*., 2006). Different citrus species including sweet orange, mandarin, lemon and lime were established at Ghibe farm using different root stocks (Volkamariana, Sour orange and Macrophylla). In addition, different scion varieties of sweet orange (Hamlin, Frost Valencia, Campbell Valencia, Jaffa, Pine Apple, Olinda Valencia); mandarine (Nova, Fair child and Clementine); lemon (Allen eureka, UCR improved); lime (Bears, Mexican) were evaluated for their resistance/tolerance to Phaeoramularia leaf and fruit spots under natural infection. Studies on these scion/root stock combinations for their resistance/tolerance to the disease are still underway at the Ghibe citrus orchard.

Table 7. Reaction of sweet orange cultivars to phaeoramularia leaf and fruit spot diseases in citrus orchard at Chagni, northwest Ethiopia, in 2003 (after Kassahun, 2004).

| Citrus cultivars | Incidence (%) | Severity index (%) | AUDPC | Premature leaf defoliation (%) | Reaction |
|---|---|---|---|---|---|
| Washington Navel | 37.43a (37.0) | 48.7a | 324.19a | 41.49a (44.0) | MS |
| Pineapple | 35.69ab (34.1) | 47.3ab | 306.8ab | 39.77a (41.0) | MS |
| Hamlin | 34.1b (31.5) | 45.0b | 282.43b | 35.04b(33.0) | MS |
| Campbell Valencia | 24.24c (17) | 15.2c | 105.42c | 26.39c (19.1) | MR |
| Jaffa | 19.47d (11.2) | 8.6d | 58.26d | 20.02d (11.8) | MR |
| Mean | 30.18 (26.13) | 33.0 | 215.42 | 32.55 (29.7) | |
| S.E.M | 3.77 | 2.008 | 311.0 | 2.118 | |
| LSD (0.05) | 2.991 | 2.623 | 27.17 | 2.242 | |
| CV (%) | 6.43 | 4 .30 | 8.19 | 4.47 | |

Means followed by the same letter in a column are not significantly different at $p \leq 0.05$. Values for disease incidence and premature leaf defoliation were arc-sin transformed; values in parenthesis are original. MS-moderately susceptible, MR-moderately resistance.

## Papaya anthracnose

Thirty-six papaya accessions obtained from the National Fruit Improvement Program at Melkassa evaluated for their resistance/tolerance to anthracnose at the Tibila farm during the 2001-2002 crop seasons showed that four accessions were resistant against papaya anthracnose (*Colletotrichum gloeosporioides*). These materials along with the available information were supplied to the breeding program for further purification studies (MARC, 2001).

### Bacterial wilt of banana

Forty banana cultivars tested for their resistance/tolerance to bacterial wilt (*Xanthomonas campestris pv. musacearum*) under artificial inoculation indicated that all of the cultivars were susceptible developing 100% infection within 120 days after inoculation, and the infection was not only on the inoculated plants but also on the mother plant, young and emerging suckers, and the whole stool, at various intensities (Wondirad *et al*., unpublished data).

## Physical methods/heat treatment

### Postharvest diseases of fruits

Hot water treatment of orange fruits at a temperature of 50 °C for five to six minutes reduced the incidence and severity of gray mold (*Penicillium digitatum*) without affecting fruit quality parameters at the Jimma University (Lemlem, 2005). Similarly, hot water treatment of fruits at a temperature of 55 °C for five minutes reduced fruit infection by mango anthracnose (*Colletotrichum gloeosporioides*). Apart from low disease incidence and severity, fruits treated with hot water using the specified temperature showed better color development, total soluble solids content, and minimum weight loss as compared with the untreated check (Etaferahu, 2005).

## Chemical control

### Phaeoramularia leaf and fruit spot of citrus

Two fungicides, Chlorothalonil 75% WP and Prochloraz 50% WP, evaluated at Jimma/ Bebeka indicated that treatment with Chlorothalonil 75% at the concentration of 0.4% reduced disease severity and gave higher marketable fruit yield, although the efficacy of both fungicides was low (Eshetu, 1999). Similar studies conducted in farmer's field around Jimma indicated that application of Kocide-101 as protective measure at the rate of 21-24 g/15 litre reduced the incidence and severity of leaf and fruit spots of citrus (Eshetu, unpublished). In other study with different fungicides for the control of Phaeoramularia leaf and fruit spot of citrus at Ghibe was found that low incidence and severity of the disease, and higher marketable yields were recorded from trees treated with Benlate, Score and Cuproxat (Tables 8 and 9 (Mohammed, 2007). In the citrus orchard at Chagni, three sprays of Benomyl/ Chlorothalonil mixture at 15 days interval starting before fruit set effectively controlled Phaeoramularia leaf and fruit spots (Table 10) (Kassahun *et al*., 2006). Alternate application of these fungicides is believed to avoid development of resistance within the populations of *P. angolensis.*

Table 8. Efficacy of fungicides on the incidence of phaeoramularia leaf and fruit spot disease of citrus at Ghibe (after Mohammed, 2007).

| Fungicides | 2000/2001 | | 2001/2002 | |
|---|---|---|---|---|
| | Incidence on leaves (%) | Incidence on fruits (%) | Incidence on leaves (%) | Incidence on fruits (%) |
| Control | 58.7 a | 67.3 a | 58.0 a | 69.3 a |
| Benomyl/Benlate | 31.0 f | 38.0 d | 31.3 f | 40.7 de |
| Kocide 2000 | 36.3 de | 48.7 c | 37.3 de | 48.3 c |
| Kocide 101 | 47.3 b | 52.0 c | 44.7 c | 49.3 c |
| Score | 32.0 ef | 41.7 d | 34.0 ef | 39.3 e |
| Copper oxychloride | 44.3 bc | 58.4 b | 48.3 bc | 58.0 b |
| Cuproxat | 40.7 cd | 48.7 c | 39.0 d | 45.7 cd |
| Cuprofix | 48.7 b | 60.3 b | 51.3 b | 58.0 b |
| Mean | 42.4 | 51.9 | 43.0 | 51.1 |
| LSD (0.05) | 4.62 | 4.18 | 3.95 | 6.0 |
| CV (%) | 12.6 | 10.8 | 14.5 | 11.4 |

Means within a column followed by the same letter(s) are not significantly different from each other at 5% probability.

Table 9. Efficacy of fungicides on the incidence of Phaeoramularia leaf and fruit spot disease of citrus at Ghibe (after Mohammed, 2007).

| Fungicides | 2000/2001 | | 2001/2002 | | |
|---|---|---|---|---|---|
| | Severity on leaves (%) | Severity on fruits (%) | Severity on leaves (%) | Severity on fruits (%) | Marketable fruit yield (kg) |
| Control | 21.4 a | 31.7 a | 21.7 a | 19.9 a | 75.6 c |
| Benomyl/Benlate | 9.1 c | 13.3 d | 11.8 de | 10.1 d | 130.7 a |
| Kocide 2000 | 14.2 b | 18.8 c | 14.3 cd | 15.2 bc | 82.3 bc |
| Kocide 101 | 16.3 b | 21.2 bc | 16.3 bc | 16.6 abc | 84.0 bc |
| Score | 8.9 c | 12.7 d | 9.9 e | 10.6 d | 124.7 a |
| Copper oxychloride | 16.3 b | 25.1 b | 17.8 abc | 19.0 ab | 79.3 bc |
| Cuproxat | 12.4 b | 19.6 c | 14.4 cd | 14.4 c | 91.8 b |
| Cuprofix | 14.7 b | 21.6 bc | 18.5 ab | 16.3 abc | 84.6 bc |
| Mean | 14.2 | 20.5 | 15.6 | 15.3 | 94.1 |
| LSD (0.05) | 3.94 | 4.4 | 3.75 | 3.64 | 15.7 |
| CV (%) | 16.1 | 12.4 | 13.9 | 13.8 | 9.6 |

Means within a column followed by the same letter(s) are not significantly different from each other at 5% probability.

Table 10. Effect of some fungicides on Phaeoramularia leaf and fruit spots on citrus variety Washington Navel at Chagni (after Kassahun, 2004).

| Fungicide treatments | Rate (a.i) | Disease incidence (%) | Disease severity index (%) | AUDPC | Leaf defoliation (%) |
|---|---|---|---|---|---|
| Benomyl | 0.078% | 14.9 (6.7)c | 12.7 (4.9)e | 34.56e | 13.2 (5.3)e |
| Chlorothalonil | 0.18% | 23.8 (16.6)b | 22.8 (15.3)c | 103.18c | 26.4 (19.9)c |
| Copper hydroxide | 0.115% | 26.4 (20.2)b | 28.7 (23.0)b | 153.19b | 32.3 (28.6)b |
| Benomyl+ Chlorothalonil | 0. 039%+ 0. 09% | 9.7 (2.7)d | 7.3 (1.6)f | 11.11f | 10.2 (3.2)f |
| Benomyl + CuOH | 0.039% + 0.056% | 21.4 (13.5)b | 18 (9.6)d | 67.07d | 23.6 (16.2)d |
| Control | - | 36.6 (35.6)a | 44.7 (49.5)a | 322.4a | 41.6 (44.1)a |
| Mean | | 22.1 (23.8) | 22.4 (26.0) | 115.25 | 24.6 (29.3) |
| S. E. M | | 11.5 | 2.1 | 222.71 | 2.9 |
| LSD (0.05) | | 5.1 | 2.22 | 22.49 | 2.6 |
| CV (%) | | 15.3 | 6.53 | 12.95 | 6.96 |

Means followed by the same letter within a column are not significantly different from each other at 5% probability. Values for disease incidence and premature leaf defoliation were arc-sin transformed; values in parenthesis are original. CuOH = Copper hydroxide.

## Papaya anthracnose

Among nine fungicides evaluated for their efficacy against papaya anthracnose at Degaga farm, Cuproxat WP at 5 l/ha), Folpan DG at 2.6 kg/ha) and Mirage at 2 kg/ha effectively controlled the disease. These fungicides were verified and recommended for registration and importation for commercial use (MARC, 2001).

## Powdery and downy mildews of grapevine (*Unicinula necatr*, *Plasmopara viticola*)

A number of fungicides were tested at Dukem, Guder, Debrezeit, Nura-Era, and Ziway farms for their efficacy against powdery mildew and downy mildew of grapevine. Application of Bayleton at the rate of 1g/liter of water at 10 days interval effectively controlled powdery mildew. Field sprays of Ridomil MZ 63.5 WP and Ridomil Gold each at the rate of 2.5g/liter were effective in controlling downy mildew (DZARC, 1999; EARO, 2000). Curzate R WP (Cymoxanil 4.2% and Copper oxychloride 39.75%) at the rate of 2.5g/l of water

were evaluated along with the standard fungicide Ridomil MZ, and were found to be effective against downy mildew of grapevine at Debrezeit and Guder (Seid, 2005).

# Conclusion and recommendations

A number of diseases are threatening fruit production in different parts of the country. Among these, Phaeoramularia leaf and fruit spot (*Phaeoramularia angolensis*), citrus canker (*X. axonopodis pv. citri*) and anthracnose (*Colletotrichum gloeosporioides*) on citrus, root rot/decline (*Phytophthora cinnamomi*) on avocado, mango anthracnose (*C. gloeosporioides*), papaya anthracnose (*C. gloeosporioides*) and dieback of papaya caused by phytoplasma were recent introductions and potential threats to fruit production in the country.

Phaeoramularia leaf and fruit spot of citrus may be controlled by application of Benlate, Score and Cuproxat at bi-weekly interval. Moreover, a mixture of Benlate and Chlorothalonil at the rate of 0.039 and 0.09 a.i./ha, respectively, can be used for effective management of *P. angolensis* on citrus. Use of moderately resistant sweet orange varieties (Campbell Valencia and, Jaffa) along with fungicide spray could be used as part of integrated management of leaf and fruit spot of citrus. Apart from fungicide application, sanitation measures such as removal of infected or dropped leaves and fruits, timely pruning of twigs with dieback symptoms also reduced the incidence and severity of Phaeoramularia leaf and fruit spot diseases of citrus. On papaya, applications of fungicides such as Cuproxat WP, Folpan DG, and Mirage, proved to be effective for the control of papaya anthracnose around the Central Rift Valley area. Moreover, sanitation measures such as removal of infected leaves of papaya at two weeks interval significantly reduced the build-up of papaya anthracnose. Powdery mildew of grapevine can be controlled by the application of Bayleton at a rate of 1g/liter of water. Where as downy mildew of grapevine can be effectively controlled by applying Ridomil MZ, Ridomil Gold and Curzate R WP at 10 days interval beginning soon after the appearance of disease symptoms. It should be understood that chemical control should be considered as a last option but not as an alternative to the principles of plant disease control. The use of integrated disease management should get priority.

Although nematodes such as *R. similis* are highly pathogenic to banana, it can be kept to the minimum infection level by using cultural and mechanical methods of control. Since nematodes do not survive in the soil for more than six months without live host tissue, rotation or fallow for the same period without the host will diminish all the nematode stages in the soil. In addition, disinfecting planting materials is very crucial since it is the main source of

inoculum. This can be done either by hot water treatment of corms at 55$^{o}$C for 15-25 minutes or nematicidal dipping (Wondirad *et al*., unpublished).

Postharvest diseases of fruits such as anthracnose and gray mold of mango and orange can be controlled using hot water treatment. Hot water treatment of fruits at temperatures of 50 to 55 $^{o}$C for five to six minutes may reduce postharvest diseases infection without losing fruit quality.

## Gaps and challenges

Due to the diverse agro-ecology of the country, there is a huge potential to produce various tropical, subtropical and temperate fruit crops in Ethiopia. However, diseases are the major production constraints of fruits. Despite the high economic importance of fruits, research efforts on the biology, epidemiology and management of diseases is still very limited. The virus complex, which is a major threat to citrus production, is not yet adequately addressed. Planting materials of different fruits for the establishment of new plantations are dispatched from the source of production without prior certification for potential diseases. The free movement of planting materials disseminates various fruit diseases to new areas. The management of crop diseases in general is mainly focused on chemical pesticides. However, use of chemicals by small-holder fruit growers may not be easy to practice mainly due to lack of technical know-how, prohibitive pesticide costs, and the strict safety precautions required for pesticide use. Moreover, frequent application of chemicals may lead to the development of resistant populations of pathogens in addition to environmental pollution.

Several experts made recommendations on fruit pathology research in the country (Bar-Joseph, 1990; GodFrey-Sam-Aggrey, 1987; Semunegus, 1985). However, none of the recommendations was implemented due to several reasons, among which lack of expertise in fruit pathology, controlled greenhouses and laboratory consumables were the major constraints. The majority of fruits like citrus, mango, and avocado are perennial trees, which can be commercially productive for several years under optimum management conditions. However, in our situation, even very young plantations of fruits are declining due to complex disease problems. Several smallholder farmers are abandoning their fruit farms mainly due to diseases. Currently, commercial farms are suffering from a complex of diseases and the prospect of obtaining at least minimum potential harvest could not be assured. A recent survey showed that phaeoramularia leaf and fruit spot disease of citrus has been causing 100% fruit losses in almost all sweet orange orchards, and making orange fruits out of production in Oromiya and southern parts of the country. Consequently, there has been very limited orange fruit supply in the market over the last 10 years.

Orange fruit infected with *P. angolensis* is not suitable for consumption due to its bitter taste. Its shelf life is also short (Ashenafi *et al*., 2006).

Banana is among the widely cultivated fruit crops both by the smallholder farmers and large scale commercial farms. However, the production and productivity of banana is still under a serious threat by nematodes. This either has forced many of the commercial farms in the Middle and Upper Awash areas to reduce the area or abandoned banana production. Banana wilt is also among the potential threats to banana and enset production especially when these crops are cultivated in close proximity with each other.

Recent surveys showed that root rot of avocado is widely distributed in all districts of Jimma, Ilubabor, Wollega and Sidamo areas. Total crop failure due to these diseases was quite common around the Jimma area including the Jimma Research Center. Root rot or decline of avocado trees has become a major problem to growers in most parts of the South and southwestern Ethiopia. Considerable post-harvest losses of fruits also occur due to a complex of fungal pathogens, which seriously affect both the local and export markets. Conservative estimates place losses of perishable commodities at 50% in under developing and tropical countries (Jeffries and Jeger, 1990). In Addis Ababa, a high (45%) incidence of post-harvest fruit infection was recorded in fruit storage houses. Although the fresh fruit market in Ethiopia has a high turn over, improvements in field production practices and the general hygiene in storage facilities and packhouses that are crucial to improve the quality of both local and export markets are not adequately developed. In general, research on post-harvest diseases of perishable fruits in Ethiopia is nearly untouched.

## Prospects

Currently, the Ethiopian Government is aggressively promoting production of fruit crops as a means of income generation and food security for subsistence farmers. The area coverage of fruit crops mainly by small holders showed tremendous increase in recent years. State owned commercial farms and private investors are also engaged in the production of various fruit crops in different parts of the country. The diversity of fruits and their production system in a diverse agro-ecology has faced a complex of disease problems that need to be tackled in a form of holistic approach. Routine disease surveys in different production areas need to be strengthened and supplemented with proper identification on the causal agents. Management options for the majority of fruit crop diseases in the country were limited to fungicide applications. Moreover, the number of fungicides currently in use is very few. Frequent application of limited number of fungicides will lead to resistance development in the pathogen population. Therefore, chemical control research should focus on

testing several fungicides from different chemical groups against major fruit diseases. It is also important to advise the commercial farmers to include a number of fungicides from different chemical groups in their spray schedules to avoid the likelihood of the development of pesticide resistance against major fruit diseases in the country. Management of fruit crop diseases should also focus on the development of non-chemical options such as cultural, host resistance and biological control. Tissue culture must also be used as a tool to multiply disease free planting materials and avoid major graft transmissible diseases during establishment of fruits to new areas.

Seedlings or planting materials for the establishment of new fruit plantations should be supported with certification programs to insure the use of disease free planting materials. In addition, for effective and sustainable production of disease free planting materials, basic facilities such as well controlled greenhouses and tissue culture laboratories should be strengthened and/or established. As part of disease management, indexing for citrus diseases with major emphasis on citrus viruses need to get research priority. This is because production of disease free planting materials is a prerequisite for establishment of new plantations.

Banana is one of the most important and potential fruit crop widely grown as source of income and food security. Since the banana nematode is one of the major limiting factors for banana production, research on the management of this disease should get priority. Banana is a natural host for bacterial wilt pathogen. Therefore, locally available and introduced banana cultivars need to be evaluated and selected for their resistance to bacterial wilt pathogen before introducing them especially in areas where enset is cultivated.

Avocado root rot caused by *Phytophthora cinnamomi* is a widespread disease with a potential of causing total crop loss. Hence, it needs immediate research intervention.

Research should put emphasis on post-harvest disease management by focusing on the exploitation of biologically active natural products as a replacement of synthetic fungicides. The potential of heat treatment and natural plant products must also be assessed for the control of the major post-harvest disease of fruits.

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# Review of Research on Diseases of Oil Crops in Ethiopia

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## Introduction

Noug or Nigerseed (*Guizotia abyssinica*), linseed (*Linum usitatisimum*), and gomenzer or Ethiopian mustard (*Brassica carinata*) are grown in the highlands at 2000-2800 masl (Getinet and Nigusie, 1996; Adefris et al., 1992). Safflower (*Carthamus tincthorius*) and sunflower (*Helianthus annus*) grow from mid (1800 masl) to low altitudes (1300 masl), while groundnut (*Arachis hypogeae*) and sesame (*Sesamum indicum*) are the major lowland (< 1300 masl) oil crops in Ethiopia (Adefris et al., 1992). The production status of these crops over the past five years is shown in Table 1. Generally, there was increasing trend in area and production of oilseeds except for sunflower. The bulk of sesame production is exported, while that of groundnut, noug, gomenzer, and linseed is processed and consumed locally. The amount of sesame exported in the first six months in 2006 was about 155, 389 tons. Groundnut and safflower seeds are the major energy and protein sources in the form of roasted snack beans mixed with barley, while noug, linseed and sesame provide edible oil.

A number of factors constrain the production and productivity of oilseeds, among which diseases are of primary importance. Among noug diseases, shot hole and blight are the most serious ones at present. In the past, however, shot hole and powdery mildew used to be serious diseases on noug (IAR, 1976). Bacterial blight causes economic damage to sesame in areas with high humidity, while phyllody is most important in semiarid areas (Teklemariam et al., 1985; Eshetu, 1986; Geremew and Asfaw, 1992; Geremew and Tefera, 1996). Wilt, powdery mildew and pasmo are the three widespread diseases of linseed. While leaf and pod spots, downy mildew and white rust were important in major gomenzer producing areas of the country (Yitbarek and Tiruwork, 1992). Cercospora leaf spots and rust have gained higher priority among groundnut diseases (Teklemariam et al., 1985; Geremew and Asfaw, 1992; Getnet et al., 1997), while safflower is severely attacked by phytophthora root

rot under humid or irrigated conditions. Sunflower production is largely threatened by downy mildew in almost all areas (Solomon, 1987).

Table 1. Area, production, and yields of oilseeds during 2001-2005.

| Crop | Production year | Area (000 ha) | Production ('000 t) | Yield (t/ha) |
|---|---|---|---|---|
| Noug | 2001 | 335.66 | 1,189.88 | 0.354 |
| | 2002 | 232.20 | 841.89 | 0.363 |
| | 2003 | 249.68 | 853.40 | 0.342 |
| | 2004 | 281.72 | 1,189.95 | 0.422 |
| | 2005 | 358.83 | 1,872.14 | 0.522 |
| Linseed | 2001 | 130.52 | 640.52 | 0.491 |
| | 2002 | 98.60 | 510.52 | 0.518 |
| | 2003 | 131.88 | 427.85 | 0.324 |
| | 2004 | 142.90 | 773.63 | 0.541 |
| | 2005 | 250.70 | 1,518.64 | 0.606 |
| Sesame | 2001 | 42.37 | 188.78 | 0.446 |
| | 2002 | 58.78 | 389.00 | 0.662 |
| | 2003 | 57.72 | 362.72 | 0.628 |
| | 2004 | 91.53 | 614.62 | 0.672 |
| | 2005 | 136.22 | 1,153.88 | 0.847 |
| Brassica | 2001 | 24.99 | 147.36 | 0.590 |
| | 2002 | 15.04 | 169.43 | 1.126 |
| | 2003 | 17.26 | 198.50 | 1.150 |
| | 2004 | 26.02 | 292.84 | 1.125 |
| | 2005 | 41.88 | 358.38 | 0.856 |
| Groundnut | 2001 | 17.20 | 152.10 | 0.884 |
| | 2002 | 16.035 | 132.85 | 0.829 |
| | 2003 | 14.088 | 107.19 | 0.761 |
| | 2004 | 20.217 | 207.15 | 1.025 |
| | 2005 | 27.08 | 290.53 | 1.073 |
| Safflower | 2001 | 1.06 | 6.47 | 0.608 |
| | 2002 | 5.47 | 37.66 | 0.688 |
| | 2003 | 3.63 | 15.82 | 0.435 |
| | 2004 | 8.40 | 50.43 | 0.600 |
| | 2005 | 9.72 | 70.39 | 0.725 |

Source: CSA, 2003, 2004 and 2005.

Despite these facts, efforts made in crop protection research were very low for this group of crops compared to that of vegetables, legumes, and cereals (Yitbarek and Tiruwork, 1992). However, there are fragmented research works on noug, sesame, linseed, gomenzer, groundnut, safflower, and sunflower pathology that needs to be compiled. This paper summarizes some of the major results of research on diseases of oil crops generated during the last 20 years in Ethiopia.

# Research findings

## Noug diseases

List of diseases recorded on noug are presented in Table 2. Getinet and Sharma (1996) reported *Phylosticta* sp. to cause tar spot on noug. However, it appears that they have misidentified *Phylosticta* for *Phoma*, which are similar to each other except that the former infects only leaf tissues and doesn't seem to deposit a tar like substance on plant tissues since it is a pycnidial fungus. Teklemariam *et al.* (1985) correctly recorded that tar spot on noug was caused by *Phyllachora* sp. Stewart and Dagnachew (1967) indicated earlier that *Phyllachora* sp. causes tar spot symptomms in many plant species in Ethiopia. Dereje and Yaynu (2001) reported that yield loss of noug from shot hole disease alone was about 10% as calculated from a fungicide screening trial, and no evidence was recorded for other diseases such as noug blight, which is currently the most serious disease of noug in the country.

Table 2. Noug diseases recorded in Ethiopia.

| **Disease** | **Pathogen** | **Status** | **Ref.** |
|---|---|---|---|
| On seed and leaf | *Alternaria dauci* | Minor | 49 |
| Leaf spot | *Alternaria porri* | Minor | 12 |
| Stem and leaf blight | *Alternaria* sp. | Major | 36 |
| Leaf gall | *Anguina amsinckia* | Minor | 49 |
| On seed | *Aspergillus* sp. | Minor | 35 |
| Downy mildew | *Bremia lactucae* | Minor | 49 |
| Leaf spot | *Cercospora guizoticola* | Medium | 12 |
| On seed | *Cladosporium* sp. | Minor | 12 |
| Not indicated | *Coniothyrium* sp. | Minor | 35 |
| Not indicated | *Emericella* sp. | Minor | 35 |
| Not indicated | *Epicoccum nigrum* | Minor | 12 |
| Powdery mildew | *Erysiphe cichoraceurum* | Medium | 12 |
| Not indicated | *Fusarium* sp. | Minor | 35 |
| Not indicated | *Helminthosporium sativum* | Minor | 36 |
| On stem | *Macrophomina phaseolina* | Minor | 12 |
| Not indicated | *Nigospora* sp. | Minor | 36 |
| On seed | *Penicillium* spp. | Minor | 12 |
| On stem, wilt | *Phoma* sp. | Minor | 6 |
| Leaf spot | *Phomopsis* sp. | Minor | 6 |
| Tar spot | *Phyllachora* sp. | Minor | 49 |
| Downy mildew | *Plasmopara halstedii* | Minor | 6 |
| Rust | *Puccinia guizotiae* | Minor | 49 |
| Damping-off | *Rhizoctonia solani* | Minor | 49 |
| Stem rot | *Sclerotinia sclerotium* | Minor | 7 |
| Shot hole (leaf spot) | *Septoria guizotiae* | Major | 36 |
| Leaf spot | *Xanthomonas guizotiae* | Minor | 49 |

## Sesame diseases

Sesame is attacked by a number of fungal, viral, bacterial mycoplasma like organisms and nematodes (Table 3). Surveys made in the Abay gorge, Arbaminch, Babile, Beles, Dansha, Didessa, Eeast Wollega, Gambella, Humera, Illubabor, Loko, Metema, Mota, Pawe, West Shewa and other sesame growing areas of the country since 1985 assessed the distribution, incidence/ severity and importance of sesame diseases in the country. Bacterial blight, phyllody, powdery mildew, wilt, leaf curl, and diseases with different viral symptoms were recorded (Geremew and Asfaw, 1992; Geremew and Tefera, 1996; MWRC, 1996; Getinet et al., 1997). Sesame blight incidence was reported to vary from 25 to 99% with severity (1-9 score) ranging from 4 to 9 (BARC, 1987). Bacterial leaf spot caused by *Xanthomonas sesami* Sabet and Bowson, or *Pseudomonasa sesami* Malakoff is reported to be damaging under conditions of high rainfall and where high humidity persists for long periods, and less damaging when sesame is grown in more arid areas under furrow irrigation (but when flood-irrigated standing water can encourage the spread of the disease) (Geremew and Asfaw, 1992). According to Eshetu et al. (1986), both pathogens (*Xanthomonas sesami* and *Pseudomonasa sesami*) may occur together or separately and can cause considerable yield reduction or complete crop failure in years of favorable conditions for disease development. The disease is widely distributed in the country, but it is often severe at Didessa, Fincha, Assosa, Dabus, Bisidimo, Babile, Gambella, Meiso, Tedele and Kobo (IAR, 1984; Teklemariam et al., 1985). At present, it is very severe at Loko, Gutin, Gambella, and Pawe; moderate at Humera, Metema and Babile, and low at Werer (IAR, 1984; Teklemariam et al., 1985, Geremew and Asfaw, 1992).

Table 3. Diseases of sesame recorded in Ethiopia.

| Common name | Pathogen | Status | Reference |
|---|---|---|---|
| Blight | *Pseudomonasa sesami* | Major | 16, 49 |
| Blight | *Xanthomonas sesami* | Major | 16, 49 |
| Phyllody | Micoplasma like organisms (MLO) | Major | 34 |
| Wilt | *Fusarium oxysporum* | Minor | 34 |
| Wilt | *Verticillium sp.* | Minor | 34 |
| Root rot | *Fusarium oxysporum,* | Minor | 34 |
| Root rot | *Rhizoctonia sp.* | Minor | 34 |
| Leaf spot | *Alternaria sesame* | Minor | 49 |
| Leaf spot | *Cercospora ssesamicola* | Minor | 49 |
| Leaf spot | *Cylindrosprium sesami* | Minor | 49 |
| Powdery mildew | *Oidium* sp.(imperfect stage)<br>*Erysiphe* sp. (perfect stage) | Minor | 31, 33, 49 |

# Disease control

## Host plant resistance

Evaluation of sesame genotypes for bacterial blight resistance started in 1981 and continued in an on and off rhythm until 2005 at different locations. Despite continued efforts, conclusive results could not be obtained due to the sporadic occurrence of the disease. However, in 1985 varieties E, Venzuela 44, Ex-Tuvan, Zira, Morada, and a number of other selections were found to be moderately resistant to blight (IAR, 1986b). Moreover, in studies conducted from 1986-1987, SPS 202-297, 202-304, 202-349, 202-514, 207-958, Acc. 214-254, B/M-09, B/M-25, B/M-28, and SPS Bako #5(81)(82) were reported to be moderately resistant (MWRC, 1996). Out of 11 advanced materials at Didessa Oro short and Morada elite were found to be resistant (BARC, 1987).

In 1993, 481 genotypes were tested at Loko and only genotype B/M #06 was reported to be resistant. Of the 95 genotypes which scored $\leq$ 3.0 in 1994 at Loko, only B/M #06 scored 1.0 (resistant), 15 entries scored 2, 24 scored 3.0 and the remaining were susceptible (MWRC, 1996). From 40 selected genotypes evaluated at Werer in 1995, genotypes B/M #06, B/M #51, PGRC/E 111-504, and PGRC/E 202-099 were found to be resistant to blight and high yielder. These 11 blight resistant/tolerant genotypes were sent to Babile, Bisidimo, and Pawe for evaluation (MWRC, 1995; 1997). These materials were evaluated at Pawe along with the susceptible check T-85 from 1996-2004 seasons and results indicated that genotypes B/M-06, Acc. No. 111-504, Acc. No. 202-514 and Abusanduk were with the lowest disease score, 1.3, 2.2, 2.6, 2.7, respectively and yielded 4-6 q/ha (Table 4). However, these materials could not maintain their tolerance in subsequent years and their yields were not better than the local variety. They also lacked uniformity in stand and seed color. Therefore, to solve the blight problem in that area another set of preliminary variety screening trial was initiated with 150 genotypes in 2004. Of these, only 17 genotypes were found to be moderately resistant. Genotypes E.W. 010(1), E.W. 002(5), and W.W 001(5) gave yields of about 9.3, 8.8 and 7.2 q/ha, respectively. The disease score on 1-9 field scale was 1.82, 1.94, and 2.19 for E.W. 010(1), E.W. 002(5), and W.W 001(5), respectively. Genotype E.W. 013(8) was moderately resistant but its yield was low (Geremew Terefe, pers. com.).

Table 4. Disease score (1-9 scale) and yield of sesame genotypes at different locations and in different years.

| Sesame genotype | Loko (1996-99) | | Pawe (1997-98) | | Werer (1995) | |
|---|---|---|---|---|---|---|
| | Disease score | Yield (kg/ha) | Disease score | Yield (kg/ha) | Disease score | Yield (kg/ha) |
| B/M # 06 | 1.3 | 357.7 | - | - | 0.9 | 13.15 |
| B/M # 09 | 3.0 | 166.7 | 2.4 | 358.5 | 1.7 | 14.14 |
| B/M # 51 | 2.6 | 255.9 | 2.55 | 380.5 | 0.8 | 11.11 |
| 54 (b) (81) (82) | 4.0 | 308.3 | 2.35 | 238 | 1.5 | 15.27 |
| Abusanduk | 2.7 | 275.8 | 2.25 | 349 | 1.2 | 14.95 |
| Acc. No. 111-504 | 2.2 | 320.8 | - | - | 0.9 | 11.11 |
| Acc. No. 202-099 | 2.8 | 454.8 | 2.1 | 382.5 | 1.0 | 13.66 |
| Acc. No. 202-103 | 2.8 | 397.3 | 2.8 | 313.5 | 1.3 | 13.92 |
| Acc. No. 202-514 | 2.6 | 460.4 | 2.5 | 354.5 | 1.2 | 11.72 |
| Acc. No. 202-516 | 2.7 | 436.1 | 2.7 | 380.5 | 1.3 | 9.94 |
| Acc. No. 203-103 | 2.8 | 444.5 | 2.4 | 284.5 | 1.6 | 11.1 |
| Check (T-85) | 4.7 | 150.2 | 3.4 | 37.5 | 2.2 | 10.29 |

Varieties evaluated for resistance to phyllody at Werer, Babile, and Bisidimo from 1984 to 1990 could not show good results because of the sporadic nature of the disease (MWRC, 1988). In the 1985 crop season, 64 out of 80 genotypes tested showed phyllody at a very low (4%) level, which appeared late (IAR, 1985; MWRC, 1986). In 1987 and there after, 230 varieties and advanced lines were screened against phyllody and only 56 genotypes developed varied level (1-44%) of infection. In the following years, the disease incidence was too low to evaluate for resistance (MWRC, 1988). Hence, no variety was found that could resist phyllody. However, the disease could be minimized by managing the jassid (*Orosius albicnatus*) vector. The studies made to identify the alternate hosts of phyllody from 1984-1989 and there after did not succeed, although recently few groundnut plants infected with phyllody were observed.

## Physical control

The effects of hot water treatment on the incidence and severity of bacterial blight, seed germination, and plant height were studied at Werer. Seed germination was significantly affected when water temperature exceeded above 60$^{o}$C (MWRC, 1995). Seeds treated with 65$^{o}$C water for 10 minutes germinated only 20%, while treatments above 65$^{o}$C did not allow seed germination at all (Geremew and Tefera, 1996). In another study conducted to determine the effective water temperature and time of exposure, seed yield was significantly higher for water temperature treatment, but not for time of exposure as well as time and temperature interactions. Disease score also did not show significant difference between treatments and the interactions but there was highly significant difference between the treated and untreated plots (Geremew and

Tefera, 1996; MWRC, 1996). As water temperature and time of exposure increased, the rate of seed germination decreased significantly (Table 5). The recommended water temperature and time of exposure for sesame seeds was 52$^{o}$C for 10-12 minutes.

Table 5. Effect of water temperature on seed germination, disease severity, and yield of sesame.

| Temperature ($^{o}$C) and exposure time (minute) | Seed germination (%) | Disease score (0-5 scale) | Yield (kg/ha) |
|---|---|---|---|
| 52 x 10 | 97.50 | 0.53 | 754.97 |
| 54 x 10 | 91.50 | 0.52 | 684.87 |
| 56 x 10 | 86.17 | 0.51 | 708.67 |
| 58 x 10 | 72.50 | 0.53 | 669.90 |
| 60 x 10 | 45.00 | 0.44 | 593.30 |
| Check (cold water) | 100 | 2. 37 | 320.10 |

## Chemical control

Streptomycin at four concentrations, 250, 500, 750, 1000 ppm evaluated on a susceptible variety T-85 against bacterial blight showed that all of the concentrations were significantly better than the untreated check both in disease control and seed yield. However, the difference among the different concentrations was not significant (MWRC, 1995). The treatment did not affect plant height and seed germination (MRRC, 1996; Geremew and Tefera, 1996). It was found that soaking sesame seeds in 1000 ppm streptomycin solution for 30 minutes reduced blight infection by 75% and increased yield by 23.6% (Table 6).

Table 6. Effect of streptomycin treatment on plant height, seed germination, disease severity and yield of sesame.

| Treatment | Germination (%) | Disease score (0-5) | Plant height (cm) | Yield (kg/ha) |
|---|---|---|---|---|
| 250 ppm | 96.0 | 0.6 | 154.54 | 849.6 |
| 500 ppm | 96.5 | 0.5 | 156.91 | 799.6 |
| 750 ppm | 96.3 | 0.5 | 156.07 | 822.4 |
| 1000 ppm | 96.5 | 0.4 | 157.13 | 887.7 |
| Check | 97.0 | 1.6 | 149.12 | 718.2 |

# Linseed diseases

## Diseases recorded

The diseases recorded on linseed are shown in Table 7. Wilt (*Fusarium oxysporium*), powdery mildew (*Oidium* sp. /*Erysiphe cichoracearum*) and pasmo (*Septoria linicola/ Mycosphaerella linorum*) were reported to be widespread and important diseases in major linseed-producing areas. Pasmo was more severe in warmer areas, while wilt occurred in cool highlands. Powdery mildew was reported to occur late in the season; hence it did not affect seed yield seriously. It was indicated that wilt caused up to 60% (average 30%) mortality of individual plants (Dereje, unpublished data).

Table 7. List of linseed diseases in Ethiopia.

| Common name | Pathogen | Status | Reference |
|---|---|---|---|
| Leaf spot | *Alternaria cinicola* | Minor | 34, 55 |
| On seeds | *Cladosporium* sp. | Minor | 36 |
| Anthracnose | *Colletotrichum linicolum* | Minor | 49 |
| Wilt | *Fusarium oxysporium* | Major | 35 |
| Root rot | *F. avenaceum* | Minor | 25, 26 |
| On seed | Helminthosporium sativum | Minor | 36 |
| Rust | Melampsora lini | Minor | 49 |
| Garcia-Rada | *Mycosphaerella linorum* | Minor | 36 |
| Powdery mildew | *Oidium* sp. (*Erysiphe cichoracearum*) | Medium | 49 |
| Root rot | *Rhizoctonia solani* | Minor | 49 |
| Pasmo disease | *Septoria linicola* | Medium | 36 |

# Disease control

## Host plant resistance

According to Adefris et al. (1992), wilt disease management studies concentrated on selection for resistant cultivar using sick plot technique. Over thousand materials were evaluated through this rigorous selection procedure from 1993-1998 seasons (HARC, 1995; 1996a; 1996b; 1998a, HARC, unpublished data). As a result, varieties, such as CI-1525, Belay, and Berene were developed and were found to perform better in wilt prone areas of West and north Shewa, Arsi and Bale. Evaluation and selection for pasmo and powdery mildew diseases were also done in conjunction with wilt selection, hence wilt resistant materials also showed good resistance to these diseases.

## Diseases of gomenzer (Brassica)

Diseases of *Brassica carinata* recorded in Ethiopia are presented in Table 8. Among these, leaf and pod spots caused by *Alternaria brassicae*, downy mildew caused by *Peronospora parasitica* and white rust caused by *Albugo candida* were reported to be widespread in major gomenzer producing areas (Yitbarek and Tiruwork, 1992). White rust and downy mildew were also reported to be widespread, but with low level of severity. Leaf and pod spot diseases were reported to be favored by humid weather conditions. The blackleg disease caused by *Leptosphaeria maculans* (anamorph = *Phoma maculans*) was serious in wet and cool areas. The disease was very severe on rapeseed (*Brassica napus*) that lack BB genome in the late 80s and halted the production of this crop in the Arsi and Bale state farms (HARC, 1992). Leaf spot caused by *Phyllosticta brassicae* was reported in the Bako area; however, the identification of the fungus was not confirmed by pathogenicity tests. Moreover, *Trichothecium roseum* showing white cover on inflorescences was reported in Holetta area.

Table 8. List of *Brassica* diseases in Ethiopia.

| Common name | Pathogen | Status | Ref. |
|---|---|---|---|
| White rust | *Albugo candida* | major | 49 |
| Leaf and pod spot | *Alternaria brassicae* | major | 49 |
| Leaf spot | *Alternaria tenuissima* | minor | 49 |
| White leaf spot | Cercosporella albomaculans | minor | 49 |
| Blackleg | *Phoma maculans* | major | 6 |
| Blackleg | *Leptosphaeria maculans* | major | 6 |
| Ring spot | *Mycosphaerella brassicicola* | minor | 49 |
| Powdery mildew | *Oidium* sp. | minor | 49 |
| Downy mildew | Peronospora parasitica | medium | 49 |
| Leaf spot | *Phyllosticta brassicae* | minor | 49 |
| Seed mold | *Rhizopus stolonifer* | minor | 36 |
| Stem rot | *Sclerotinia sclerotiorum* | minor | 4 |
| White cover on head | *Trichothecium roseum* | minor | 6 |
| Black rot | *Xanthomonas campestris* | minor | 36 |
| Leaf-curl | *Leaf-curl Virus* | minor | 4 |
| Root knot nematode | *Meloidogyne* sp. | minor | 49 |

Yield losses due to leaf and pod spots on gomenzer were estimated to be 8 - 11% (Awgechew and Eshetu, 1986), and 14% (Dereje and Yaynu, 2001) from fungicide screening trials conducted at Holetta. Leaf spot is primarily a seed-borne disease, which causes pre- and post-emergence damping-off. Similarly, blackleg was reported to cause up to 62% yield losses as estimated from variety screening trials (Yitbarek, unpublished data). Yield loss data on other diseases of gomenzer are not available.

# Disease control

## Host plant resistance

A resistance breeding work was started at Holetta in the 1990s to transfer resistance gene(s) from *B. carinata* to *B. napus*. About 200 germplasm and segregating populations were screened and tolerant/ resistant materials were selected for further tests (HARC, 1998b; 1996b; 1995; HARC, unpublished data). Out of 48 materials screened in 1992, 128 single plant selections (SPS) were obtained with mortality range of 22-80%. Out of 92 materials tested in the 1994 season, only 2 lines (G 4061/5 x Pure 92-9 and Kuyu 9/3 x Tower sel 3/92-14) were moderately resistant. The mortality range of the materials was 35-77%. It was reported that severity of blackleg varied with seasons, mean mortality in 1992 was 51.6%, and increased to 85.8% in the 1993 season.

## Cultural control

Control of diseases on gomenzer is well described in EARO (2003). Blackleg of gomenzer can be controlled by effective stubble management and 3-4 years crop rotation (Yitbarek, 1992).

## Groundnut diseases

Diseases of groundnut are listed in Table 9. Of these, early and late leaf spots or Tikka disease and rust are important (MWRC, 1986; 1988).

Table 9. List of groundnut diseases in Ethiopia.

| Common name | Pathogen | Status | Ref. |
|---|---|---|---|
| Early leaf spot | *Cercospora arachidicola* | major | 33 |
| Late leaf spot | *Cercospora personata* | major | 33 |
| Rust | *Puccinia arachids* | major | 33 |
| Gray mold | *Botrytis* sp. | minor | 52 |
| Storage mold | *Aspergillus niger* | minor | 32 |
| Storage mold | *Aspergillus flavus* | major | 32 |
| Wilt | *Fusarium* sp. | major | * |
| Pepper spot | *Alternaria* sp. | major | 52 |
| Root and crown rot | *Aspergillus* sp. | minor | 32 |
| Root and crown rot | *Rhizoctonia* sp. | major | 32 |
| Root rot | *Rhizopus* sp. | minor | 52 |
| Leaf spot | *Cladosporium* sp. | minor | 52 |
| Leaf spot | *Penicillium* sp. | minor | 52 |
| Leaf spot | *Phomopsis* sp. | minor | 52 |
| Stem rot | *Sclerotium rolfsi* | minor | * |
| Stem rot | *Aspergillus niger* | minor | * |
| Phyllody | MLO | minor | 32 |
| Peanut mottle virus/rosette? | ? | major | 30, 39 |

* = Own findings

The leaf spot diseases cause yield reduction of 65% in areas with high rainfall (Teklemariam et al., 1985). Diseases with minor economic importance include root rot, wilt, stem rot, kernel rot, and crown rot (Stewart and Dagnachew, 1967; IAR, 1982; Teklemariam et al., 1985; Geremew and Asfaw, 1992). Later surveys in different groundnut growing areas recorded cercospora leaf spots, rust (*P. arachids*), pepper spot (*Alternaria* sp.), anthracnose (*Colletotrichum* sp.), bunchy top, crown rot (*Aspergillus* sp.), leaf blotch, different leaf spots and leaf curl viral diseases (MWRC, 1996).

### Basic study

A study made on groundnut rust mode of seed transmission and effect of temperature on the longevity of uredospores in greenhouse at HARC showed that uredospores stored at 25$^{o}$C and above decreased viability with increase in storage time. Seeds coated or internally inoculated with viable uredospores were found to be healthy when grown indicating that seed transmission is unlikely to result in rust infection (Awgechew, 1987).

## Control of groundnut diseases

### Host plant resistance

Several genotype screening works have been conducted at Abobo, Babile, Bisidimo, Didessa, Loko, Pawe, and Werer for leaf spot and rust resistance. These diseases infected all tested genotypes, however, the level of resistance to leaf spot and rust varied significantly. Most of the genotypes tested showed a high disease severity and yield was not obtained from most plots due to heavy defoliation of leaves in different years depending on weather conditions. However, there were genotypes with varying degree of resistance to leaf spot and rust at different locations. Leaf spot resistant variety screening trial conducted at Didessa state farm in the 1987/88 crop season on 23 genotypes identified ICG 7793 to be resistant, while ICG 7730 and ICG 2519 were tolerant to cercospora species (BARC, 1987).

The variety screening trials conducted from 1981-1984 against rust at Werer ended without success due to the absence of uniform disease infection. The trials were moved to Babile and Bisidimo where they were conducted from 1985-1989. Over 350 lines and varieties were evaluated at the two locations. Due to the sporadic occurrence of the disease, it took long time to complete the trials, and only few genotypes such as Chalambana, PI-315608, PI-313608, PI-298115, Israel, NC-2, NC-4, and Argentina were found moderately resistant (IAR, 1985; MWRC, 1987; 1988; 1996). Another set of variety screening for rust resistance was conducted at Babile and Loko using 208 accessions along with Shulamith and Robout 33-1 (susceptible checks) from 1995- 1999. The

disease incidence was 100% with severity varied from 2-9 on a 1-9 field scale. No immune variety could be identified, but variations were observed among genotypes ranging from moderately resistant to highly susceptible (MWRC, 1995; 1997; 2000). Studies carried out at Loko from 1993 to 1999 for leaf spot resistance indicated that genotypes ICG 270, ICGV 863457, ICG 2917, PI 381622 and IGFDN-29 were resistant, and ICG 9224 and Oldhalle were moderately resistant, although the pod yields were only 9-17 q/ha (MWRC, 1995). In 1998 and 1999, 12 leaf spot resistant materials were evaluated for yield and disease reaction at Pawe. The highest pod yield of 13.1 q/ha was obtained from genotype ICG-9224 followed by ICGV 86347 (12.3 q/ha). However, the lowest disease score of 3.0 was recorded on ICGV-86347. The 12 resistant genotypes selected from the previous trials were again evaluated for leaf spot resistance at Werer in 2000, and at Loko in 2001. Genotypes ICG-7273, ICG-9261, PI-381622, ICG-25, and ICG 7476 were proved resistant to leaf spot diseases at both locations. At Werer, under irrigation the genotypes varied significantly in yield ranging from 9-37 q/ha. Pod yields of 37.5, 36.7, and 32.4 q/ha were obtained from ICG-2530, ICG-7476, and ICG-9224, respectively (MWRC, 2000). In the 2004/05 season, 75 new accessions evaluated at Pawe for leaf spot resistance ranged from moderately susceptible to susceptible in their reaction to leaf spot (Geremew unpublished).

Leaf defoliation was very heavy on genotypes susceptible to both leaf spot and/or rust. The percentage defoliation was highly correlated with disease severity, and out of 210 materials, only 40 genotypes showed low (< 5%) level of defoliation (MWRC, 1995). Genotypes tolerant to leaf spot and/or rust showed low (< 10%) level of defoliation, while resistant genotypes were not defoliated at all. Generally, genotypes ICG-270, ICG 2917, ICG 7476 and PI-381622 were resistant to leaf spot and rust over years and locations but yielded very low at both locations. Therefore, these materials could be used in future breeding program as disease resistant gene sources and for yield improvement (MWRC, 2000).

From 1991 to 1996, efforts were made to investigate the potential of released varieties and those in the pipeline for mold (*Asvergillus* sp.) resistance. A study made on 11 genotypes showed that *in vitro* seed colonization by *Aspergillus flavus* was significantly different. Low level of Aspergillus contamination was recorded on genotypes ICG-2519, ICG-9088, NC-4X and J 11 (Amare et al., 1995). Attempts were made from 1995 to 1998 at Werer and Babile to determine the critical time of Aspergillus invasion in the field; reaction of advanced aflatoxin resistant lines developed at ICRISAT to seed infection and consequently aflatoxin elaboration, but no further aflatoxin alnalysis was made. However, at Werer the aflatoxin resistant lines (ICG-86/68, ICGV-2519, ICG-9088, and J 11) gave yields in the range of 54-74 q/ha. At Babile and Pawe,

yields were low and varied from 7-18 q/ha for resistant entries, and about 12 of them had an average yield of 16 q/ha (MWRC, 1996; 2000).

## Chemical control

Fungicide spray against groundnut rust conducted between 1984-1988 at Bisidimo with Fluatrifol 12.5% EC/SC at 0.8 l/ha, Chlortriafol 5% SG at 0.7 kg/ha, Dimethylmorpholina 80% EC at 250 ml/500 liter of water), Triadimenol 250 EC at 75 g/ha, Bravo 500 EC at 2 l/ha, and Benlate 50% WP at 500 g/500 liter water did not give any conclusive result due to the sporadic nature of the disease (MWRC, 1987). The high leaf defoliation due to the early leaf spot interfered with the rust incidence; hence it was recommended that the leaf spot should first be controlled before spraying for rust (MWRC, 1996).

Studies conducted from 1996-1998 to determine the efficacy and rate of the fungicide chlorothalonil 85% WP in controlling leaf spot at Babile showed that spraying at the rate of 3.3, 4.4, 5.5 and 6.67 kg/ha at 15 days interval starting from the onset of the disease provided effective control. There was a significant difference between the fungicide treatments and the untreated check. However, the difference among the different rates of chlorothalonil was not significant (MWRC, 1997). The lesion diameter was significantly reduced in the fungicide treatments, which ranged from 0-0.6, while in the untreated check it was from 2-8 mm. Therefore, leaf spot could be controlled by applying 3.3 kg/ha of chlorothalonil as of disease onset.

## Safflower diseases

Surveys made from 1985 to 2005 to safflower growing areas of the country, namely Debre Zeit, Bisidimo, Gursum, Didessa, Mota and Werer revealed the occurrence of many diseases such as *Ramularia* and *Alternaria* leaf spots, rust, *Fusarium* sp., Phythophtora root rot and head blight (Table 10) (IAR, 1985; Meseret, 1987). The fungus *Fusarium oxysporum f.* sp. *carthami* causes wilt disease in farmers' fields at Debre Zeit and Werer, and in some humid or high rainfall areas. Rust is widespread in all safflower-growing areas but it is minor in importance. Meseret (1987) reported that safflower landrace/ cultivars planted at different times on light and heavy soil types at Debre Zeit varied as planting time and soil type differed. On the light soil, early planting manifested more type and severe disease as compared to late planting on heavy soils except rust (Meseret, 1987).

Table 10. Safflower diseases recorded in Ethiopia.

| Common name | Pathogen | Status | Ref. |
|---|---|---|---|
| Leaf spot | *Ramularia carthami* | major | 49 |
| Leaf spot | *Septoria centrophylli* | minor | 30, 32 |
| Leaf spot | *Alternaria carthami* | - | 52 |
| Leaf spot | *Epicocum nigrum* | - | 52 |
| Leaf spot | *Phyllosticta carthami* | - | 52 |
| Leaf spot | *Cercosporella carthami* | - | 52 |
| Bacterial leaf spot | *Xanthomonas guizotiae* | - | 52 |
| Head rot | *Botrytis cinerea* | minor | 30 |
| Root rot | *Phytophthora dreschleri* | major | 49 |
| Root rot | *Phytophthora.parasitica* | major | 52 |
| Stem rot | *Sclerotinia sclerotiorum* | minor | 52 |
| Wilt | *Fusarium oxysporum* f.sp. *carthami* | minor | * |
| Powdery mildew | *Leveillula taurica* | minor | 49 |
| Rust | *Puccinia carthami* | minor | 49 |
| Shot hole | *Septoria* sp. | minor | 52 |
| Leaf and bract blight | *Pseudomonas* sp. | - | 52 |
| Damping off | *Rhizoctonia solani* | minor | 52 |

* = Geremew pers. observation.

## Sunflower diseases

Surveys made in sunflower growing state farms (Anger, Awassa, Bilito, Bir valley, Herero, Sheneka, Sinkile, Ukie, and Wondo Tika) and other parts of the country recorded a number of diseases on sunflower (Table 11).

Table 11. Sunflower diseases recorded in Ethiopia.

| Common name | Pathogen | Status | Ref. |
|---|---|---|---|
| Downy mildew | *Plasmopara halstedii* | major | 13 |
| Rust | *Puccinia helianthi* | major | 13, 49 |
| Stem and head rot | *Sclerotinia sclerotiorum* | major | 49 |
| Leaf spot | *Septoria helianthi* | major | 49 |
| Alternaria leaf spot | *Alternaria helianth* | minor | 13 |
| Leaf spot | *Phoma oleracea* | minor | 13 |
| Leaf blight | *Fusarium equiseti* | minor | 52 |
| Bacterial leaf spot | *Pseudomonas helianthi* | minor | 49 |
| Powdery mildew | *Oidium* sp. (*Erysiphe cichoracearum*) | minor | 49 |
| Southern blight | *Sclerotinia rolfsii* | minor | 52 |
| Wilt | *Verticillium alboatrum* | - | 13 |
| White rust | *Albugo tragoponis* | - | 13 |
| Leaf and bract blight | *Pseudomonas* sp. | - | 52 |
| Damping off | *Rhizoctonia solani* | minor | 52 |
| Root knot nematode | *Meliodegyne* spp. | minor | 49 |

- = unknown

Out of these, downy mildew (*Plasmopora halstedii*), stem and head rot (*Sclerotinia sclerotiorum*), rust (*Puccinia helianthi*), and leaf spot (*Alternaria helianthi*), were found to be widespread and economically important (Teklemariam et al., 1985; Solomon, 1987; Terefe, 1990; Mesfin, 1992).

### Basic study

Epidemiology and mode of transmission of sunflower downy mildew (*Plasmopara halstedii*) was studied (as soil and seed inoculation) under greenhouse conditions at HARC, and results showed that all of the survived heads were infested by downy mildew showing that infection was from soil to the seed and from the seed to the mother plant (Awgechew, 1985). In the seed inoculation study 25 seeds infected with downy mildew were incubated at 22-24$^{o}$C and after the presence of oospores was confirmed the seeds were planted in pots with sterilized soil and kept in the greenhouse at RH of 80% and temperature of 30$^{o}$C. Results indicate that most of the plants were dead at seedling stage and the few plants survived to maturity have produced oospores and mycelia of downy mildew. Seed transmission rate varied from 22-100%. Generally, both studies have proved that *Plasmopara halstedii* is seed transmitted disease of sunflower (Awgechew, 1985).

Studies conducted in 1984/85 and 1985/86 to determine effective methods of isolation, culturing and inoculation of stem or head rot (*Sclerotina sclertiorum*) of sunflower at HARC revealed that the best method of isolation and culturing identified was first to sterilize in 1% mercuric chloride (HgCl) solution for 30 seconds, rinse it in distilled water and then plant on sterilized barley and incubate at 25$^{o}$C. High disease development was obtained when seed, root/collar and head were inoculated (Teklemariam, 1987a).

## Control of sunflower diseases

### Cultural study

The effect of sowing date on the incidence of downy mildew studied at the Awassa Research Center indicated that downy mildew incidence increased with a delay in sowing dates. The lowest (3%) diseases incidence was recorded from June 7 sowing, and the highest (50%) from the late sowing (July 7). Therefore it is suggested that sunflower should be sown from the first week up to the third week of June with the onset of rains to escape disease incidence and obtain high yield (Solomon, 1984; 1986; Teklemariam et al., 1985).

### Host plant resistance

Sunflower varieties were screened for downy mildew resistance on sick plots developed at the Awassa Research Center. Among the evaluated local collections and introduced materials with a history of resistance, genotypes RHA-274, RHA-296, HA-821, PP-720, DM-BR-53, DM-74, DM-134, BR-51, and 83-1447 were found to be resistant to downy mildew (Solomon, 1986). Lines such as HA-822, DM-77, RHA-298, Sputunik, DM-188, CMS-HA-282, DM-52, DM-263, and 83-1171 have shown from 0.3% to 0.5% infection. All of the local collections were found to be susceptible to downy mildew (Solomon, 1984; 1987).

Forty sunflower cultivars and hybrids evaluated for root knot nematode resistance in sick plots, under field and glasshouse conditions showed that all of the materials tested were susceptible with 80-100% galled roots (Mesfin, 1992).

### Chemical control

A study conducted at the Awassa Research Center from 1985/86 to 1986/87 to control downy mildew of sunflower by using seed dressing chemicals identified Metalaxyl to be very effective when applied at the rate of 210 g a.i./100 kg seed (IAR, 1986a; Solomon, 1987; Teklemariam, 1987b).

## Conclusion and recommendations

- The sesame variety screening conducted at Didessa against bacterial blight identified Oro short and Morada elite as resistant. At Bisidimo, genotypes E, Venzuela 44, Ex-Tuvan, Zira, Morada, SPS 202-297, 202-304, 202-349, 202-514, 207-958, Acc. 214-254, B/M-09, B/M-25, B/M-28, and SPS Bako #5(81)(82) were found moderately resistant. While genotypes B/M #06, B/M #51, PGRC/E 111-504, and PGRC/E 202-099 were resistant to blight at Loko. At Pawe, genotypes E.W. 010(1), E.W. 002(5), and W.W. 001(5) gave very high yield and showed low disease score. Generally, no genotype showed resistance across locations. However, there existed resistance/tolerance for specific locations. Therefore, these genotypes could be verified in the respective locations for their resistance to bacterial blight of sesame and/or could be used as gene sources in future breeding program.
- For the phyllody resistance could not be identified due to the sporadic occurrence of the disease. The tentative recommendation is to manage the jassid (*Orosius albicnatus*) that transmits the diseases.
- Recent reports indicate the occurrence of phyllody on groundnut plants, hence, precautions must be taken when the two crops (groundnut and sesame) appear in a field at the same time.

- Sesame seeds could be treated at a water temperature of 52$^{o}$C for 10-12 min. in order to control seed borne bacteria.
- Sesame seeds could be soaked in 1000 ppm streptomycin solution for 30 min. to reduce blight infection. Re-infection of treated seeds at field level should be avoided or minimized.
- To date, very few genotypes were advanced and released as a variety, but still linseed growing areas of West and North Shewa, Arsi and Bale could use varieties such as CI-1525, Belay, and Berene for wilt control.
- A number of gomenzer lines and single plant selections (SPS) were screened for blackleg resistance out of which 2 lines (G 4061/5 x Pure 92-9 and Kuyu 9/3 x Tower sel 3/92-14) were found moderately resistant. Thus, these lines could further be verified or be used as gene source in the future gomenzer breeding program.
- Out of numerous groundnut genotypes screened for rust resistance at Babile, Bisidimo and Werer only a few genotypes such as Chalambana, PI-315608 and PI-298115 were found moderately resistant. As these genotypes are low in pod yield, they should only be used as gene source in the breeding program.
- Among the many groundnut accessions evaluated for leaf spot resistance at Didessa and Loko State farms, Pawe and Werer Research centers, genotypes ICG 7793, ICG 270, ICGV 86347, ICG 2917, PI 381622, IGFDN-29, ICG-9224 and ICGV 86347 were resistant. Out of which genotypes ICG-9224 and ICGV 86347 showed resistance across locations and gave the highest pod yield. Therefore, in the absence of resistant variety, these genotypes could be verified across locations and released as a variety.
- Groundnut genotypes ICG-270, ICG 2917, ICG 7476 and PI-381622 were resistant to leaf spot and rust over years and across locations but yielded very low at Loko and Pawe. Therefore, these materials could be used in future breeding program for disease resistant variety development and yield improvement.

## Gaps and challenges

The currently grown varieties of sesame are low in yield and susceptible to diseases and this hindered wide adaptation of released varieties. The attempts made in developing widely adapted and disease resistant sesame and groundnut varieties were minimal and or otherwise unsuccessful due to lack of concerted effort and expertise. The genotype screening studies in all oil crops lacked continuity, and even the identified resistant genotypes were not exploited in the breeding program. Studies on the distribution and severity of diseases are scanty and targeted loss assessment study is lacking, and no clear evidence on the pathology of noug blight. Most control measures recommended for

gomenzer disease were from that of rapeseed, and hence, research evidence should be generated for it under specific conditions. Screening for disease resistance is lacking for important diseases such as leaf and pod spot of gomenzer, noug blight, pasmo and powdery mildew of linseed. Production of disease-free seed and improvement through seed treatment is lacking for seed transmitted diseases such as leaf and pod spot of gomenzer, blight of noug and sesame, downy mildew of sunflower, and pasmo of linseed. The development of high-yielding and disease resistant varieties is essential in general.

## Future

Systematic surveys are necessary that quantify diseases in the different agro-ecologies

- Yield losses should be determined, as this should guide the future strategy of disease management in oil crops.
- Exploitation of the available genetic resources through genetic manipulation or gene engineering.
- Strong and with continued breeding program should be launched to develop resistant, high yielding and early maturing varieties.
- Works on production of high quality oil seeds, determination of economic threshold levels, cultural control, and development of integrated disease management systems should be given primary attention in future on oilseeds in general.

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# Advances in Coffee Diseases Research in Ethiopia

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## Introduction

Ethiopia is currently the first in Africa and the seventh largest Arabica coffee producer in the world (ICO, 2005). The average annual production amounts to more than 200,000 tones and 90% of the produce is from garden, semi-forest and forest coffee systems by small-scale farmers, while nearly 10% of the produce comes from large-scale plantation coffee. Coffee is by far the number one export crop and contributes decisively to the country's foreign currency income (Workafes and Kassu, 2000). In addition, the economic value of *C. arabica* genetic resources contained in Ethiopian highland rainforests was estimated to amount around USD 1458 million and USD 420 million at a 5 and 10% respective discount rates (Hein and Gatzweiler, 2006). This commercially as well as genetically valuable crop is attacked by a number of pre- and post harvest diseases, and of these diseases, coffee berry disease (CBD), coffee wilt disease (CWD) and coffee leaf rust (CLR) are the most important in Ethiopia. CBD is by far the most economically important disease causing up to 100% losses in some places (Van der Graaff, 1981; Merdassa, 1986; Tefestewold and Mengistu, 1989; Eshetu and Girma, 1993) although the national average yield losses estimated between 25 and 30% (Tefesetewold, 1995; Eshetu *et al.*, 2000a). CWD is a troublesome soil-borne disease that totally kills the coffee tree, is prevailing in almost all coffee growing regions with national average disease incidence of about 27.9% (CABI, 2003; Odour *et al*., 2005). CLR occurs in most coffee areas but occasionally pronounced in the garden and plantation coffee with 27% severity infestation in Hararghe (Meseret *et al*., 1987; Meseret, 1991; Eshetu *et al*., 2000b). Fungal mould (*Aspergillus* and *Penicillium* spp.) contaminations of coffee associated with mycotoxins such as ochratoxin-A (OTA) is becoming concerns of importing-consuming countries and entailing preventive measures (Girma *et al*., 2007b).

Disease management strategies give first priority to the deployment of resistant cultivars. The existence of untapped genetic resources of *C. arabica* fortunately lead to develop more than 15 CBD resistant coffee cultivars (through selection and rigorous testing) within a period of 8 years. This period was relatively short

for a perennial crop like coffee. This genetic potential not only saved plenty of expenditure on the purchase of fungicides and spray equipments but also prevented the risks associated with use of pesticides. This review covers results of research on coffee diseases for the last two decades (1986-2006) in Ethiopia.

## Diseases survey and record

A number of diseases along with causal pathogens have been identified and documented on Arabica coffee in Ethiopia (Table 1). Diseases like damping-off of coffee seedlings commonly caused by *Fusarium*, *Pythium*, *Rhizoctonia* and *Mucor* spp. occur in most nurseries (Seyoum, 1993; Eshetu *et al*., 2000b), while other diseases attack different parts of the coffee plant in the field. Some diseases are introduced from elsewhere and pose serious damage to the coffee bean, while others are endemic and attack roots, stems, branches and leaves of the plant. Armillaria root rot is becoming important in garden, semi forest and plantation coffees with an estimated tree loss of 10% in Yirgachefe, Kochore and Dale areas in the southern region (Girma, 2004). Coffee bean discoloration/rot attributed to infection of a bacterial pathogen (*Pseudomonas syringae*) has been reducing the quality and marketable quantity of coffee (Merdassa, 1986; Eshetu *et al.*, 2000b). Aschochyta twig dieback and leaf blight are unimportant coffee diseases on unstumped trees although it causes considerable retarded growth or death of new shoots and succulent leaves emerging after stumping old coffee trees. Moreover, *Cercospora coffeicola* Berk. and Cke is usually regarded as a minor nursery pathogen but Harar coffee types are observed to be very susceptible (Van der Graaff, 1981; Eshetu *et al.*, 2000b). Some species of *Aspergillus*, *Penicillium* and *Fusarium* have been identified in mouldy beans sampled from southwestern parts of Ethiopia (Abraham, 2006; Girma *et al*., 2007a).

Although most of these diseases are less damaging to the crop that might have emanated from co-evolution processes between the host and the pathogens over centuries, diseases such as coffee berry disease, coffee wilt disease and leaf rust caused, by C*olletotrichum kahawae* Waller and Bridge, *Gibberella xylarioides* Heim and Saccas (*Fusarium xylarioides* Steyaert) and *Hemileia vastatrix* Berk. and Br., respectively, have been menacing coffee production with significant impacts on the quantity and quality of the crop in almost all coffee growing regions of the country (Merdassa, 1986; Meseret, 1991; Girma, 1997; Eshetu *et al.*, 2000a; 2000b).

Table 1. Coffee diseases recorded and their status in Ethiopia.

| Disease | Causal Pathogen | Status | References |
|---|---|---|---|
| Coffee berry disease | *Colletotrichum kahawae* Waller & Bridge (*C. coffeanum* Noack (sensu Hindorf)) | Most important | 7, 26, 37 |
| Coffee wilt disease (tracheomycosis) | *Gibberella xylarioides* (Heim & Saccas) (*Fusarium xylarioides* Steyaert) | Most important | 4, 8, 16, 20, 26 |
| Coffee leaf rust | *Hemileia vastatrix* Berk. & Br. | Important | 8, 26, 27 |
| Armillaria root rot | *Armillaria mellea* (Vahl ex Fries) Kummer | Locally important | 8, 26 |
| Collar/ bark disease | *Fusarium eumartii*, *F. stilboides* Wollenw, *F.solani* (Mart.) Sacc., *F. oxysporum* (Schl.) Wellman, *F. lateritium var. longum* Wollenw. | Locally important | 16, 17, 18, 26 |
| Bean discoloration/rot | *Pseudomonas syringae* van Hall | Locally important | 8, 37 |
| Brown eye-spot | *Cercospora coffeicola* Berk. & Cke. | Less important | 8, 26 |
| Brown blight | *Colletotrichum gloeosporioides* Penz., *C. kahawae* Waller & Bridge | Unimportant | 8, 26, 37 |
| Ascochyta leaf blight & shoot die-back | *Ascochyta tarda* Stewart | Less important | 8, 26 |
| Thread blight | *Corticium koleroga* (Cke) Hohnel | Locally important | 8, 26 |
| Seedling damping-off | *Pythium* spp., *Rhizoctonia* spp., *Fusarium* spp., *Mucor* spp. | Less important | 8, 26, 34 |
| Elgon/branch dieback | *Pseudomonas syringae* | Unimportant | 26 |
| Coffee moulds | *Aspergillus auricomus, A. flavofurcatus, A. fuliginosus A. melleus, A. parasiticus, A. phoenicis, Penicillium stoloniferum* | Less important | 10 |

## Status of coffee berry disease

The prevalence of coffee berry disease was assessed in different regions of Ethiopia at various times (Van der Graaff, 1981; Merdassa, 1986; Tefesetewold, 1995; Eshetu *et al.*, 2000a). In 1994, the mean CBD incidence was 38.8% in Oromia Regional State and 17.2% in Southern Nations Nationalities and Peoples Regional state (SNNPR) (JARC, 1997). The highest severity was recorded at Bedele (69%) followed by Gore (50%), while the lowest was at Mugi (17%) in Oromia. In SNNPR, the highest was recorded at Yirgachefe (34%) whereas the lowest was at Dilla (6%). The average severity of the disease in six zones of Oromia was about 31.1% in the year 2000, the highest being in Hararghe, and the least in Illubabor (Melaku and Samuel,

2000). Similarly, CBD ranged between 22 and 63% in the major coffee growing zones of SNNPR (Tesfaye and Sinedu, 2000) (Table 2). Tesfaye and Ibrahim (2000) studied disease status in Amhara, Gambella and Benishangul Gumuz coffee growing areas and reported an estimated severity of over 38% in Amhara. The national average coffee yield loss attributed to CBD varied between 25 and 30% (Tefesetewold, 1995; Eshetu *et al.*, 2000). The earlier loss estimated by Merdassa (1986) was between 50 and 80%. The intensity of CBD was very high in all coffee growing areas of the country, especially at higher altitudes and in valley bottoms in many areas of the southern region.

Table 2. Severity (%) of CBD in Oromyia and SNNPR (1997-1998).

| **Oromia** [1] | | | **SNNPR**[2] | | |
|---|---|---|---|---|---|
| **Zone** | ***Wereda* (n)** | **Mean (%)** | **Zone** | ***Wereda* (n)** | **Mean (%)** |
| Jimma | 7 | 32.0 | Sidama | 5 | 22.0 |
| Illubabor | 7 | 19.0 | Gedeo | 4 | 32.5 |
| West wollega | 8 | 22.6 | N. Omo | 6 | 39.6 |
| East Hararge | 2 | 41.0 | Hadiya | 3 | 52.7 |
| West Hararge | 5 | 42.0 | Gurage | 4 | 63.0 |
| Borena | 2 | 30.0 | Amaro | 2 | 38.0 |
| Mean | | 31.1 | Mean | | 41.3 |

[1] Adapted from Melaku and Samuel, 2000, [2] Adapted from Tesfaye and Sinedu, 2000.

## Prevalence of coffee wilt disease

Coffee wilt disease also known as tracheomycosis occurs in almost all coffee fields under forest, semiforest, garden, and plantation coffee production systems in the areas surveyed. The magnitude and extent of damage varied among and within coffee fields, districts, and the production systems, depending on various factors such as the genetic makeup and age of coffee, cultural practices and prevailing climatic conditions. The disease incidence was higher in plantation coffee mainly in research centers, small-scale farmers' holdings (1 to 5 ha) and in large estate commercial plantations (> 10 ha) of Bebeka, Limmu, and Teppi (Girma, 1997; Girma and Hindorf, 2001b; Girma, 2004). The mean incidence in semiforest coffee ranged from 3.6% at Teppi to 19% at Mettu, while in plantation coffee the lowest was 17.3% at Toba and the highest was 65.2% at Bebeka (Fig. 1). CWD was found to be serious in the farmers' coffee plantations at Gera, Chira and Gechi districts (*weredas*), with respective mean incidences ranging from 21.7 – 25.5%, 32.3 – 77% and 35 – 60% (Girma, 2004) (Table 3). Likewise, it was prevalent in garden coffee in the southern region, specifically in the major coffee producing districts of the Gedeo Zone with higher incidence in Yirgacheffe followed by Kochore and Wonago (Girma and Hindorf, 2001a; Girma, 2004).

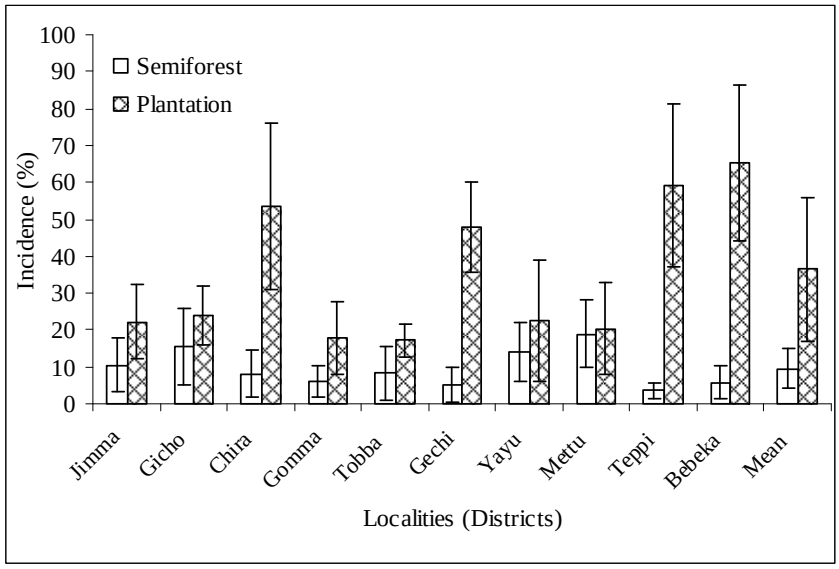


Fig. 1. Incidence of coffee wilt disease in the semiforest and plantation coffee production systems in southwestern Ethiopia in 2001 (Girma, 2004).

The nation wide surveys of CWD showed that on average 27.9% of the 1607 sampled coffee farms were infested, and the disease was found in all of the regions surveyed, with incidences ranging from 14.9-34.0% and severity ranging from 1.3%-5.0% (Fig. 2) (CABI, 2003; Odour *et al*., 2005). The incidence and severity of CWD in SNNPR were 34% and 5.0%, respectively, and these were significantly ($P < 0.001$) higher than that of in other regions. It was particularly high in Yirgacheffe, Kochore, and Wonago *weredas* of Gedeo Zone with a mean incidence of 90% and severity of 24%. The incidence was above 35% in West Gojam, West Wollega, Bench Maji, and Sidama Zones. The annual coffee yield reduction due to CWD was estimated at about 1.7%, which was equivalent to a yield loss of 16.7% amounting to more than 3.8 million USD (CABI, 2003). These losses coupled with the difficulty to control the disease strongly suggest that CWD is the most important disease of coffee in Ethiopia.

Table 3. Percentage incidence of coffee wilt disease in farmers' plantation coffee in southwestern Ethiopia.

| Location | Field | Estimated area (ha) | Incidence (%) | |
|---|---|---|---|---|
| | | | range | mean |
| Gera | Gicho 1 | 1.0 | 11.5 – 35.0 | 24.5 |
| | Gicho 2 | 1.5 | 8.7 – 38.0 | 21.7 |
| | Sedi-Loya | 1.0 | 23.9 – 27.1 | 25.5 |
| Chira | Gure-Genji | 5.2 | 38.0 – 75.0 | 51.5 |
| | Chira 1 | 4.5 | 55.0 – 89.0 | 77.0 |
| | Chira 2 | 1.5 | 14.0 – 42.0 | 32.3 |
| Tobba | Yachi | 0.3 | 12.1 – 20.8 | 16.5 |
| | Kilole | 0.4 | 14.6 – 23.9 | 19.3 |
| | Ageyu | 0.2 | 8.3 – 27.0 | 16.1 |
| Gomma | Shashamene | 0.5 | 12.7 – 19.4 | 10.8 |
| | Echemo | 0.3 | 12.5 – 15.5 | 13.6 |
| | Sombo | 0.2 | 25.8 – 34.2 | 29.2 |
| Gechi | Kamp | 0.5 | 25.0 – 70.0 | 48.9 |
| | Mine-kobba | 5.0 | 15.0 – 55.0 | 35.0 |
| | Asendabo | 5.0 | 37.7 – 78.6 | 59.7 |
| Yayo | Jitto | 1.0 | 11.0 – 34.0 | 22.5 |
| Mettu | Sor | 0.5 | 8.0 – 33.3 | 20.4 |
| Mean | | | 8.3 – 89.0 | 30.9 ± 18.2 |

Source: Girma, 2004.

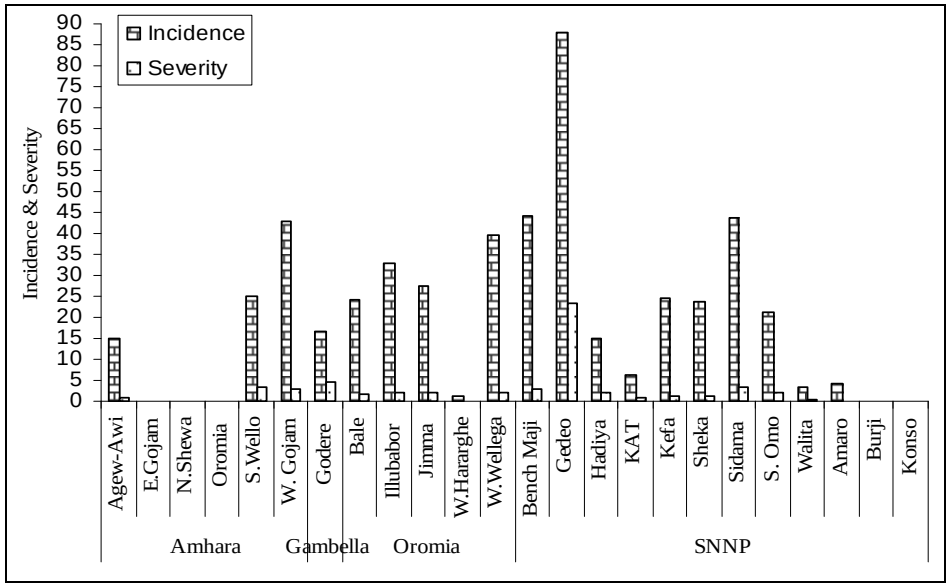


Fig. 2. Incidence and severity of coffee wilt disease in different regions and zones of Ethiopia in 2002 (CABI, 2003).

## Coffee leaf rust

Coffee leaf rust (CLR) occurs in most coffee areas with varying intensities, and the highest incidence and severity was recorded on Harar coffee types in Hararghe (Merdassa, 1986; Meseret *et al*., 1987; Eshetu *et al*., 2000b). The average amount of attacked trees was 12.9% in 1980 and increased to 36.3% after 10 years in 1990 (Table 4). The normal log arithmetic rate (r) disease increase per annum was estimated at 3.3% (Meseret, 1991). Eshetu *et al*. (2000b) reported as high as 27% coffee leaf rust severity in Hararghe and this might be attributed to the distribution of susceptible host and occurrence of virulent races. Despite its occurrence in most coffee growing regions of the country, yield loss due to CLR was not yet determined.

Table 4. Coffee leaf rust incidence in five major coffee growing regions of Ethiopia.

| Administrative Region | 1980 | | | 1987 – 1990 | | |
|---|---|---|---|---|---|---|
| | Districts (n) | Fields (n) | Incidence (%) | Districts (n) | Fields (n) | Incidence (%) |
| Keffa | 9 | 14 | 15.1 | 8 | 17 | 42.5 |
| Illubabor | 7 | 18 | 7.8 | 6 | 17 | 41.8 |
| Wollega | 5 | 16 | 12.9 | 5 | 16 | 24.7 |
| Sidamo | 6 | 20 | 12.2 | 6 | 23 | 32.7 |
| Hararghe | 4 | 21 | 17.1 | 7 | 22 | 39.6 |
| Total | 31 | 89 | | 32 | 95 | |
| Mean | | | 13.0 | | | 36.3 |

Source: Meseret, 1991.

## Moulds associated with coffee beans

Seven fungal species belonging to the genera *Aspergillus* (6) and *Penicillium* (1) were detected in different coffee samples collected from southwestern Ethiopia (Table 5) (Girma *et al*., 2007a). The observed mycofloral populations varied significantly across sample components and geographic origins of coffee. *Aspergillus phoenicis* was abundantly isolated from coffee cherries dried on the tree and in wet processed parchment coffee from Gera and Jimma. *A. parasiticus* was dominant mould species (81.5%) detected in coffee samples fallen and dried on the ground at Teppi. Over 87.5% of *A. melleus* was found in fallen coffee beans, while 45% was observed in dried coffee samples collected from the tree at Jimma. *Penicillium stoloniferum* was recorded most frequently in coffee samples collected at Gera followed by Teppi. *A. ochraceus*, the most toxigenic species was not encountered in the samples (Girma *et al*., 2007a), although Abraham (2006) reported the occurrence of this species in smaller proportions (7.4%) of which only 17.1% was capable of producing ochratoxin-A (OTA).

Table 5. Frequency of mould mycoflora identified from coffee beans in southwestern Ethiopia.

| Coffee mould mycoflora spp. | Beans from the ground | | | Beans from the tree | | | Parchment coffee | | |
|---|---|---|---|---|---|---|---|---|---|
| | Gera | Jimma | Tepi | Gera | Jimma | Tepi | Gera | Jimma | Tepi |
| *Aspergillus flavofurcatus* | 2.7 | 0.0 | 7.5 | 0.0 | 0.0 | 0.0 | 12.5 | 0.0 | 0.0 |
| *A. fuliginosus* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 |
| *A. melleus* | 5.0 | 87.5 | 7.4 | 7.4 | 46.8 | 13.8 | 16.3 | 15.9 | 17.2 |
| *A. auricomsus* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 | 0.0 | 0.0 | 0.0 |
| *A. parasiticus* | 6.2 | 0.0 | 81.5 | 10.7 | 0.0 | 18.7 | 15.0 | 0.0 | 15.3 |
| *A. phoenicis* | 44.7 | 40.5 | 0.0 | 90.0 | 99.2 | 15.0 | 90.9 | 19.1 | 57.6 |
| *Penicillium stoloniferum* | 44.2 | 6.7 | 0.0 | 11.8 | 0.0 | 29.9 | 70.8 | 6.9 | 41.5 |

Source: Girma *et al*., 2007a.

# Biological studies

## Pathogenicity of CBD isolates

Tefesetewold (1995) distinguished the CBD pathogen from other *Colletotrichum* spp. associated with Arabica coffee in Ethiopia based on thorough analyses of cultural, morphological, biochemical and physiological characteristics. However, he failed to support the new species name *Colletotrichum kahawae* introduced by Waller *et al*. (1993) that the first nomenclature of *C. coffeanum* Noack (sensu Hindorf) was based on berry samples taken from Brazil where the disease does not exist. The results of two independent studies evidenced no host specialization (physiologic races) in the CBD pathogen populations in Ethiopia (Tefesetewold, 1995; Arega, 2006). Tefesetewold (1995) tested 6 isolates sampled in Keffa, Sidamo and Hararghe on 3 CBD resistant cultivars (741, 744 and 74110) and a landrace from Sidamo (Kurme) and found significant variations in aggressiveness among the isolates (Table 6).

Table 6. Pathogenicity of 6 *Colletotrichum kahawae* isolates on seedlings of 4 coffee selections 23 days after inoculation in growth chambers (after Tefesetewold, 1995).

| Coffee cultivar[1] | *Colletotrichum kahawae* isolates[2] | | | | | |
|---|---|---|---|---|---|---|
| | H# Harar | H#37 | S#104 | S#1152 | K#46 | K#Kaffa |
| 741 | 0.0 g | 0.0 g | 0.0 g | 0.0 g | 0.0 g | 0.0 g |
| 744 | 36.8 e | 26.7 ef | 0.0 g | 14.6 fg | 0.0 g | 0.0 g |
| 74110 | 93.7 ab | 95.8 ab | 79.6 bc | 89.9 abc | 98.0 ab | 89.6 abc |
| Kurme | 100 a | 70.8 cd | 55.3 d | 79.2 bc | 60.0 d | 83.3 abc |

[1] Coffee cultivar 741, 744, and 74110 were released CBD resistant selections, Kurme represented Sidamo local land races. [2] Codes H, S and K refer respectively to isolates from Hararghe, Sidamo and Keffa. Means followed by the same letters are not significantly different from each other (DMRT) LSD value = 17.48; SD = 6.14.

Similarly, 12 *C. kahawae* isolates sampled from four afromontane rainforest sites (Harenna, Bonga, Sheko and Yayu) and in seedlings of three widely grown CBD resistant cultivars and a susceptible check indicated significant differences in aggressiveness (Table 7) (Arega, 2006).

Table 7. Pathogenicity of 12 *C. kahawae* isolates collected from afromontane rain forest coffee areas inoculated with seedlings of three CBD resistant and susceptible cultivars in growth room (after Arega, 2006).

| Isolate[1] | Coffee cultivar[2] | | | | Mean[3] |
|---|---|---|---|---|---|
| | 741 | 754 | 74110 | 370 | |
| H40 | 14.0 gh | 20.3 g | 88.7 b-d | 100 a | 55.8 AB |
| H41 | 12.7 gh | 17.8 gh | 85.3 b-e | 100 a | 54.0 A-C |
| H43 | 14.2 gh | 15.4 gh | 78.3 d-f | 98.0 a | 51.5 CD |
| B52 | 20.2 g | 17.9 gh | 89.5 bc | 100 a | 56.9 A |
| B53 | 16.5 gh | 13.8 gh | 86.6 b-e | 100 a | 54.2 A-C |
| B55 | 17.7 gh | 18.9 gh | 77.8 d-f | 98.3 a | 53.2 B-D |
| S60 | 12.3 gh | 13.7 gh | 80.3 c-f | 100 a | 51.6 B-D |
| S61 | 10.7 gh | 14.3 gh | 76.9 ef | 97.6 a | 49.9 D |
| Y70 | 9.0 h | 15.0 gh | 79.0 d-f | 100 a | 50.8 CD |
| Y73 | 14.6 gh | 18.5 gh | 92.7 b | 98.3 a | 56.0 AB |
| Y75 | 16.0 gh | 10.8 gh | 21.0 g | 70.3 f | 29.5 E |
| G81 | 21.8 g | 9.3 h | 79.3 d-f | 98.3 a | 52.2 B-D |
| | 15.0 L | 15.5 L | 78.0 K | 96.7 J | |

[1] *Colletotrichum kahawae* isolates coded with 'H, B, S, Y and G were collected, respectively from Harenna (Bale), Bonga, Sheko, Yayu and Gera. [2] Coffee cultivar 741, 7454 and 74110 are CBD resistant cultivars, 370 was CBD susceptible check. [3] Means followed with the same letter(s) are not significantly different according to DMRT. Least significant difference (LSD) values (P = 0.05) for the cultivars, the isolates and the interactions comparisons are 2.1, 3.7 and 7.3, respectively. CV = 9.5%.

## Pathogenic diversity in *Gibberella xylarioides* population

In the pathogenicity test that consisted of 11 isolates and 9 cultivars from Arabica and Robusta coffees, it was found that the Arabica isolates were pathogenic only to seedlings of Arabica coffee with significantly varying degrees of aggressiveness across cultivars, but incompatible with that of Robusta coffee seedlings (Girma, 2004; Girma *et al*., 2005). In contrast, the Robusta strain was specifically compatible with seedlings of Robusta coffee without showing any infection symptom in all Arabica cultivars. There were highly significant ($P < 0.001$) differences among Arabica cultivars, the isolates and cultivar-isolate interactions in seedling death and incubation periods (Table 8). These suggested the presence of horizontal resistance in the host, aggressiveness in the pathogen and vertical resistance/virulence combinations, respectively (Girma, 2004; Girma *et al*., 2005). Strains collected in the recent CWD outbreaks on Robusta coffee in the Democratic Republic of Congo

(RDC002), Uganda (CAB003) and Tanzania (TZ008, TZ009) were pathogenic to all seedlings of eight Robusta coffee lines, but did not cause infection on Arabica coffee (Girma *et al.,* 2007b). These two findings were consistent with the previous report of Girma and Mengistu (2000) but it was not congruent with the work of Pieters and Van der Graaff (1980).

Table 8. Percent wilt of *Coffea arabica* and *C. canephora* seedlings inoculated with 11 *Gibberella xylarioides* isolates collected from various geographic origins in greenhouse (after Girma *et al.,* 2005).

| **Isolates**[1] | ***Coffea arabica* cultivars** | | | | | ***Coffea*** | **Mean** [2] |
|---|---|---|---|---|---|---|---|
| | **Catimor-J19** | **7440** | **F-59** | **Caturra Rojo** | **2485** | ***canephora*** | |
| Gx1 | 30.6 p–r | 66.2 f-j | 90.0a | 83.5 a-c | 78.2 a-f | 0.0 v | 58.1 B |
| Gx2 | 19.9 r-u | 52.5 j-n | 78.2a-f | 81.7 a-d | 69.6 c-i | 0.0 v | 50.3 C |
| Gx3 | 17.4 r-u | 30.8 p-r | 64.6f-j | 64.9 f-j | 50.3 k-o | 0.0 v | 38.0 E |
| Gx4 | 27.9 q-s | 65.8 f-j | 83.9ab | 85.7 ab | 80.3 a-e | 0.0 v | 57.3 B |
| Gx5 | 8.8 uv | 30.5 p-r | 67.3e-i | 47.6 l-o | 44.6 m-o | 0.0 v | 33.2 E |
| Gx6 | 8.3 uv | 42.3 n-p | 77.4a-f | 65.2 f-j | 68.4 d-i | 0.0 v | 43.6 D |
| Gx7 | 24.3 r-t | 62.7 g-k | 81.7a-d | 81.8 a-d | 68.9 d-i | 0.0 v | 53.2 BC |
| Gx8 | 14.4 tu | 27.1 q-t | 75.0b-g | 58.7 h-l | 38.0 o-q | 0.0 v | 35.5 E |
| Gx9 | 15.0 s-u | 57.5 i-m | 85.7ab | 81.6 a-d | 62.5 g-k | 0.0 v | 50.4 C |
| Gx11 | 77.2 a-f | 86.0 ab | 81.5a-d | 90.0 a | 72.2 b-h | 0.0 v | 67.8 A |
| Gx12 | 0.0 v | 0.0 v | 0.0 v | 0.0 v | 0.0 v | 84.1 ab | 14.0 F |
| Mean | 22.2 T | 47.4 S | 71.4 P | 67.4 Q | 57.6 R | 7.6 U | |

[1] *G. xylarioides* isolates sampled from collections from Jimma (Gx1), Gera (Gx2), Chira (Gx3), Gechi (Gx4), Yayu (Gx5), Metu (Gx6), Tepi (Gx7), Bebeka (Gx8), Ayraguliso (Gx9), Yirgachefe (Gx11), Uganda (Gx12), respectively. Percent wilt was calculated from cumulative number of dead over total number of seedlings (20/ treatment) 6 months after inoculation, and the actual wilt values were arcsine-square root transformed. [2] Means followed with the same letter(s) are not significantly different from each other and least significant difference (LSD) values (P = 0.05) for the cultivars, the isolates and the interactions comparisons are 3.5, 4.7, and 11.6, respectively. CV = 15.8%.

The RAPD-PCR analysis of 22 *G. xylarioides* strains of the recent and historical collections from Arabica, Robusta and Excelsa coffees indicated that the Ethiopian Arabica isolates are clustered into a single homogeneous population, although distinctly polymorphic to the recent and historical strains from the other coffee species (Fig. 3) (Girma *et al*., 2005). The historical Arabica strain (1971) was slightly different from all the recent isolates (2001) in Ethiopia illustrating little genetic change in the population structure over the past three decades. The host-pathogen interactions and RAPD-PCR markers corroborated the existence of host specialization at least two pathogenic forms within *G. xylarioides* populations. These studies lead to designate *formae speciales*, namely; *Gibberella xylarioides* f. sp. *abyssiniae* (anamorph: *Fusarium xylarioides* f. sp. *abyssiniae*) for the fungus strains attacking only

*Coffea arabica* and limited to Ethiopia, and *G. xylarioides* f. sp. *canephorae* (anamorph: *F. xylarioides* f. sp. *canephorae*) pathogenic to *C. canephora* and *C. excelsa* (Girma 2004; Girma *et al*., 2005; 2007b).

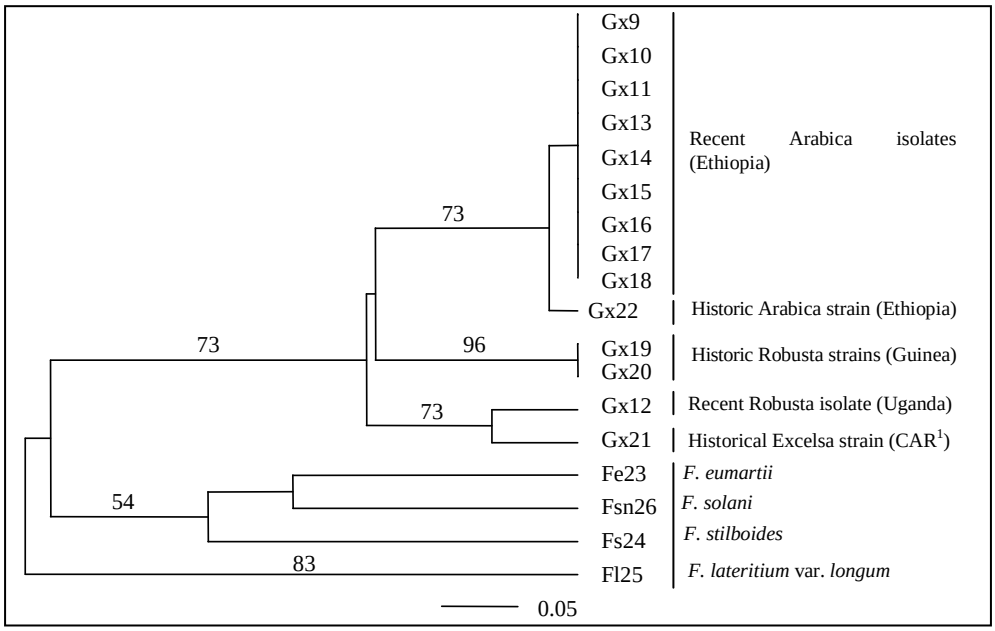


Fig. 3. Clustering of *Gibberella xylarioides* strains from *Coffea arabica*, *Coffea canephora* and *Coffea excelsa* and other *Fusarium* spp. based on genetic similarity coefficients or distance matrix of RAPD profiles produced with five primers generated by UPGMA. (Numbers on the branches indicate the confidence intervals obtained by bootstraping with 500 replications).
[1]CAR = Central African Republic.
Source: Girma *et al*., 2005.

*G. xylarioides* produces perithecia in dark stromatic fruiting bodies in the barks of stems of dead coffee trees in the field after 2 – 3 months (Van der Graaff and Pieters, 1978; Girma *et al.*, 2001; 2004). These structures were mostly observed around the crown region of the plants and occasionally higher on the stem and branches of the trees and in artificially inoculated coffee seedlings. Mating tests and crosses of some isolates of the fungus were compatible and yielded mature perithecia with typical ascospores of the species in culture. *In vitro* development of fertile perithecia helps understand the genetic structure of the fungus populations such as gene flow and inheritance of traits like virulence/ aggressiveness (Girma, 2004; Girma Adugna *et al*., 2007c).

### Distribution of physiologic races of *Hemileia vastatrix*

Meseret *et al.* (1987) tested about 243 rust isolates collected from 45 coffee districts (W*eredas*) on coffee differential groups and detected five physiologic races, namely race I, II, III, X and XV (Table 9). Among these; race III was the most prevalent (53.1%) in southwest forest coffee areas of Kaffa, Illubabor, and Wollega; but less common in plantation coffee. Race II was the second (40%) widely distributed in garden and plantation coffees, while race X, which had not been encountered in earlier rust sample collections, was recorded at Choche and Bonga coffee forests with diverse host populations (Meseret *et al.*, 1987).

Table 9. Composition and distribution of physiologic races of coffee leaf rust in major coffee areas (after Meseret *et al.*, 1987)

| Region | Rust samples (n) | Coffee leaf rust races (gene for virulence) | | | | |
|---|---|---|---|---|---|---|
| | | I ($V_2V_5$) | II ($V_5$) | III ($V_1V_5$) | X ($V_4V_5$) | XV ($V_1V_4V_5$) |
| Keffa | 76 | 0 | 14 | 53 | 9 | 0 |
| Illubabor | 25 | 0 | 4 | 20 | 1 | 0 |
| Wollega | 30 | 0 | 12 | 18 | 0 | 0 |
| Gamo Goffa | 10 | 0 | 4 | 6 | 0 | 0 |
| Sidamo | 37 | 0 | 16 | 21 | 0 | 0 |
| Shewa | 26 | 0 | 14 | 8 | 0 | 4 |
| Hararge | 34 | 0 | 30 | 2 | 0 | 2 |
| Gojam | 3 | 0 | 3 | 0 | 0 | 0 |
| Total | 241 | 0 | 97 | 128 | 10 | 6 |
| Percent (%) | 100 | 0.8 | 39.9 | 52.7 | 4.1 | 2.5 |

# Epidemiological studies

### Coffee berry disease and climatic conditions

The occurrence and intensity of CBD varies from place to place and from one season to the other, depending largely on host susceptibility, pathogen aggressiveness and favourable weather conditions. The disease is very severe and causes appreciable yield loss in areas where the temperature is relatively low and relative humidity is high, mainly in the rainy seasons. A partial regression-correlation of disease parameters (severity and incidence of CBD) recorded for 10 years on the progenies of 13 released CBD resistant selections and a susceptible standard at Gera (CBD hotspot area) as dependent variables against major weather factors such as temperature (maximum, minimum), rainfall (amount and number of rainy days) and relative humidity documented during disease development period as independent variables were analysed. Among the meteorological parameters, the mean maximum temperature showed significantly negative correlation with CBD severity in berry count ($r = -0.88$) and visual assessment ($r = -0.76$), while the total number of rainy days (r

= 0.72) and relative humidity (r = 0.71) exhibited significantly positive relationship (Girma, 1995). The analysis demonstrated prevalence of low temperature accompanied by high rainfall extended over a longer period of time favoured CBD development and increased the disease intensity (Girma, 1995) as indicated by Van der Graaff (1981). In southern and south eastern regions with bimodal rainfall pattern, CBD is a serious problem on local coffee landraces grown in valley bottoms where relative humidity is higher and moisture is sufficient to cause severe infection. Thus, although these conditions prevail at higher altitudes (> 1850 masl), it is not only elevation that detrimentally amplify CBD intensity rather the conducive weather conditions that occur even at lower altitudes. Van der Graaff (1981) indicated that low temperatures between 20 and 22 $^{o}$C and relative humidity close to 100% or presence of water droplets at least for 5 hours should be maintained in growth room/chamber during CBD seedling hypocotyl inoculation test.

## Epidemiological studies on coffee wilt disease

There is no systematic epidemiological study conducted on CWD to date, however, some preliminary observations indicated that temperature, rainfall, topography, coffee tree age, shade, soil type and weeding methods had significant effects on the incidence of the disease. The incidence was higher on coffee trees planted on loamy soil, shaded, older and weeded by slashing (CABI, 2003). *G. xylarioides* was isolated from leaf, branch, stem and roots samples of infected coffee trees (Table 10). The fungus was found produce persistent perithecia containing enormous number of viable (90-95% germination) ascospores after killing the plant in the field. These serve as survival and dissemination structures and are important sources of inoculum in the CWD epidemics (Girma and Hindorf, 2001a; Girma, 2004; Girma *et al*, 2007c). Among the factors contributing to spread of CWD in Ethiopia are frequent replacing/ replanting with several seedlings (3 - 8) for each wilted tree after uprooting (CABI, 2003). Girma (1997) and Girma *et al*. (2001) indicated that the infections of the young replants undoubtedly implicate that the fungus survives in stumps, root debris, or the soil for 2 to 3 years.

Table 10. Proportions of *G. xylarioides* from various parts of the plant (afer Girma *et al*., 2001).

| Plant parts | Symptom groups | | | |
|---|---|---|---|---|
| | Apparently healthy | Partially wilting | Completely wilted | Dead trees |
| Stem | 7.7 | 85.2 | 83.3 | 54.5 |
| Branch | 0.0 | 68.0 | 57.9 | 50.0 |
| Root | 23.1 | 72.0 | 70.0 | 29.4 |

### Factors influencing incidence and distribution of coffee leaf rust

Since coffee is an evergreen perennial crop, leaf rust epidemics carry on with some fluctuations from season to season, depending on the rainfall and temperature. In addition to climatic factors, coffee production systems, biotic agents, altitude and shade levels are attributed to variations in leaf rust infection (Meseret, 1996). The onset of rust was observed from October to January attaining peak infection levels between November and December at higher altitudes and monomodal rainfall areas (Meseret, 1991). Conversely, the infection increased from August to November with peak in September at lower altitudes. *Verticillium* spp. was recorded as hyperparasites of the fungus in many areas, indicating that it can be a potential agent for the management of the disease (Meseret, 1991; Meseret, 1996).

## Host resistance

### Development of CBD resistant cultivars

Merdassa (1986) reviewed the ever successful crash program of CBD resistant selection and appraisal program that ultimately resulted in the release of more than 15 resistant coffee cultivars in the shortest time in Ethiopia. Since then great efforts have been made adopting similar selection scheme and testing procedures in search for CBD resistant coffee within the heterogeneous populations. As a major component of origin-specific coffee landrace development program, selecting CBD resistant mother trees and testing their progenies have been in progress. The selection methodologies and testing procedures have been optimized in that the *ex situ* detached berry test was replaced by the *in situ* attached berry test jointly supported by intensive seedling test under controlled growth room conditions for efficient screening and appraisal of CBD resistance (Girma and Chala, 2008).

More than 1308 coffee mother trees were selected from Hararghe (348), Limmu (280), Sidamo (373) and Wollega (307) between 1985 and 2005 (Table 11). Coffee progenies of outstanding performance have already been advanced to verification plots in the fields at Haru and Mugi (West Wollega), Micheta and Mechara (West Hararghe), and Konga and Korkie (Sidamo) (Table 11). Eight coffee selections viz. 7418, 74153, 7514, 7516, 7576, 75129, 8136 and 827, which are as resistant as the standard checks (741 and 75227) were identified and recommended for release (Girma and Chala, 2008). Of these, five selections have been recently approved for production in southwestern Ethiopia. To date, about 20 released CBD resistant cultivars are in production in major coffee growing areas of the country except in Hararghe.

The nature of resistance to CBD is believed to be horizontal (Van der Graaff 1981; Mesfin and Bayetta, 1984; Bayetta, 2001), and the inheritance of the resistance is controlled by recessive genes. Disease susceptibility showed partial to complete dominance over resistance. The inheritance mechanism is nonetheless a debatable issue between the Ethiopian (Mesfin and Bayetta, 1984; Bayetta, 2001) and Kenyan breeders (Van der Vossen and Walyaro, 1980; Van der Vossen, 2007). This situation apparently limited resistance breeding and use of coffee hybrids for CBD control.

Table 11. CBD resistant selections of coffee mother trees and their progenies promoted to verifications between 1985 and 2005.

| Region | Selection years | No of tested selections | No of promising progenies |
|---|---|---|---|
| Hararghe | 1985, 1998, 2002 – 2005 | 348 | 14 |
| Limmu | 1985, 2001, 2003 – 2005 | 280 | 0 |
| Sidamo | 1985, 1994 – 1997 | 373 | 14 |
| Wollega | 1998 – 2001 | 307 | 14 |
| Total | | 1308 | 42 |

Source: summarized by the authors.

## Development of CWD resistant cultivars

Significant differences were reported in the percentage of dead trees caused by *G. xylarioides* under field conditions at Gera, Bebeka, Jimma, and Tepi (Girma, 1997; Girma and Hindorf, 2001b; Girma *et al.;* 2001; Girma, 2004). The loss of coffee cultivars SN-5, F-51/53 and 248/71 was 100%, whereas F-35 and F-51 had significantly ($P < 0.05$) low death rates, 9.3 and 27.9%, respectively at Gera (Table 12) (Girma *et al.*, 2001). At the same locality in another field planted with 1981 CBD resistant selections (n = 30) including both wilt resistant and susceptible checks also revealed differences in disease incidence ranging from 12.2% for selection 8150 to 95.6% for the susceptible check, 74304. Selection 74141 (resistant check) showed susceptibly reaction with high number of tree death (Table 13) (Girma and Hindorf, 2001b).

The field performance of some coffee cultivars was generally consistent with the results of seedling tests. Girma and Mengistu (2000) reported that cultivars 74165 and 35/85 that had low disease levels under field conditions showed high resistance at seedling stage. On the other hand, cultivars 24/85 and F-17 that were moderately resistant in the field became susceptible to the aggressive isolates in the greenhouse (Table 14). SN-5 and 74304 were highly susceptible both at seedling stages and maturity (Table 12, 14, 15) (Girma and Mengistu, 2000; Girma and Hindorf, 2001b, Girma and Chala, 2008). In repeated seedling

inoculation experiments, cultivars 1579, 20071 and 8136 were consistently resistant to CWD with mean death rates of 12.7, 15.2 and 25.3% (Table 15) (Girma and Chala, 2008). However, about 77% trees of the cultivar 20071 were severely attacked (Table 12), while tree mortality of cultivar 8136 was 29.4% (Table 13) in the field showing tolerance to CBD (Girma *et al*., 2001; Girma and Hindorf, 2001b).

Table 12. Percentage tree death in some cultivars of national coffee collections at Gera (after Girma *et al*., 2001).

| **Coffee cultivars** | **Incidence (%)** |
|---|---|
| F-3 | 38.0 e - h |
| F-6/1 | 58.8 b – g |
| F-6/2 | 45.7 d - g |
| F-17 | 46.8 d - g |
| F-34 | 35.7 f - h |
| F-35 | 9.3 h |
| F-51 | 27.9 gh |
| F-53 | 95.5 a |
| F-51/53 | 99.8 a |
| F-57 | 92.8 ab |
| 4/70 | 72.4 a - e |
| 18/70 | 83.6 a – c |
| 29/70 | 69.2 a - f |
| 31/70 | 68.7 a - f |
| 52/70 | 76.9 a - d |
| 69/70 | 77.6 a – d |
| 146/71 | 93.2 ab |
| 200/71 | 76.6 a – d |
| 201/71 | 86.0 ab |
| 206/71 | 91.6. ab |
| 248/71 | 99.2 a |
| 741 | 49.0 c - g |
| SN-5 | 100.0 a |
| Mean | 69.3 |
| LSD ($P < 0.05$) | 30.7 |
| CV | 26.9 |

Means followed by the same letter(s) are not significantly different from each other (DMRT).

Table 13. Incidence of coffee wilt disease in 1981 CBD resistant selections in the field at Gera (Girma and H. Hindorf, 2001b).

| Coffee Selection | Incidence (mean %) |
|---|---|
| 813 | 94.1 ab |
| 814 | 26.3 de |
| 815 | 49.9 a - e |
| 816 | 39.0 c - e |
| 817 | 48.8 a – e |
| 8112 | 63.1 a - e |
| 8116 | 56.4 a -e |
| 8118 | 33.2 c - e |
| 8121 | 35.2 c - e |
| 8123 | 38.6 c – e |
| 8128 | 76.5 a - d |
| 8133 | 19.2 e |
| 8136 | 29.4 c - e |
| 8138 | 82.5 a – c |
| 8140 | 35.9 c - e |
| 8142 | 38.4 c – e |
| 8143 | 42.4 b - e |
| 8144 | 37.0 c - e |
| 8146 | 34.6 c - e |
| 8148 | 56.2 a - e |
| 8149 | 63.4 a - e |
| 8150 | 12.5 e |
| 8151 | 53.5 a - e |
| 7395 | 30.0 c – e |
| 74140 | 43.3 b - e |
| 741 | 35.2 c - e |
| 754 | 56.3 a - e |
| 74141 (resistant) | 79.5 a – d |
| 74262 | 80.7 a – c |
| 74304 (susceptible) | 95.6 a |
| Mean | 49.5 |
| LSD value | 43.3 |
| CV (%) | 53.4 |

Means followed with the same letters are insignificantly ($p < 0.05$) different according to DMRT.

Table 14. Seedling death of nine coffee cultivars inoculated with four *G. xylarioides* isolates in the greenhouse at Jimma, 1997 (after Girma and Mengistu, 2000).

| Coffee Cultivars | *Gibberella xylarioides* Isolates[1] | | | | |
|---|---|---|---|---|---|
| | Gx12 | Gx26 | Gx31 | Gx43 | Mean |
| 74165 | 0.00 j | 40.52 e - i | 33.93 f- i | 22.59 g- j | 24.26 E |
| 7440 | 0.00 j | 17.12 h - j | 11.61 ij | 19.28 h - j | 12.01 F |
| 74304 | 0.00 j | 64.55 a - f | 48.82 b - h | 38.03 f - i | 37.85 CD |
| F-17 | 0.00 j | 77.79 a - c | 52.60 a - g | 75.05 a - d | 51.36 AB |
| F-61 | 0.00 j | 54.75 a - g | 57.10 a - f | 70.80 a - e | 45.66 BC |
| SN-5 | 0.00 j | 70.80 a - e | 62.37 a - f | 46.80 c - h | 44.99 BC |
| 35/85 | 0.00 j | 43.81 d - h | 35.25 f - i | 35.97 f - i | 28.76 DE |
| 24/85 | 0.00 j | 73.82 a - d | 82.97 a | 85.19 a | 60.49 A |
| 61/85 | 0.00 j | 80.37 ab | 85.10 a | 85.10 a | 62.64 A |
| Mean | 0.00 N | 58.17 M | 52.18 M | 53.42 M | |

[1] Gx12, Gx26, Gx31, and Gx43 were *G. xylarioides* isolates collected from Bebeka, Teppi, Jimma and Gera, respectively. Means followed with the same letter(s) are not significantly ($P < 0.05$) different from each other according to Duncun's Multiple Range Test (DMRT). LSD values for the cultivars, the isolates and the interactions comparisons were 10.8, 9.2, and 27.6, respectively.

Table 15. Resistance levels of some coffee cultivars to coffee wilt disease and incubation periods (days) for symptom development at seedling stage (after Girma and Chala, 2008).

| . Coffee cultivars | Actual value (mean % death) [1] | Transformed Value[1] | Incubation period (mean no. of days) |
|---|---|---|---|
| 1185 | 86.0 | 75.1 ab | 90.0 op |
| 1785 | 78.7 | 67.9 a-h | 80.0 p |
| 1579 | 12.7 | 16.9 s | 157.5 a |
| 2179 | 63.3 | 53.4 i-o | 140.8 a-d |
| 4/70 | 77.2 | 62.0 b-l | 117.5 d-m |
| 36/70 | 60.9 | 56. f-n | 92.5 n-p |
| 146/71 | 34.6 | 35.1 qr | 122.5 d-k |
| 200/71 | 15.2 | 20.3 s | 152.5 ab |
| 206/71 | 52.8 | 46.1 m-q | 125.0 d-j |
| 8112 | 74.9 | 63.2 a-k | 112.5 f-o |
| 8133 | 64.2 | 54.1 g-n | 122.5 d-k |
| 8136 | 25.3 | 29.6 rs | 150.0 a-c |
| 8143 | 61.6 | 52.7 j-p | 125.0 d-j |
| 8144 | 40.2 | 39.1 o-r | 137.5 a-e |
| F-27 | 81.0 | 67.0 a-j | 90.0 op |
| F-35 | 85.7 | 70.9 a-e | 97.5 l-p |
| Cattura | 68.9 | 59.2 d-m | 130.0 b-h |
| Geisha | 88.1 | 73.9 a-c | 97.5 l-p |
| 7440 * | 40.4 | 38.7 p-r | 135.0 a-f |

Table 15. Contd.

| Coffee cultivars | Actual value (mean % death) [1] | Transformed Value[1] | Incubation period (mean no. of days) |
|---|---|---|---|
| SN-5 ** | 69.7 | 56.7 e-n | 119.2 d-l |
| Mean | 68.8 | 58.3 | 115.5 |
| LSD (P < 0.05) | | 14.4 | 23.5 |
| CV (%) | | 21.8 | 17.9 |

[1] The actual data (2 years) were transformed to arcsine/square root before analysis.
* resistant/tolerant check;** susceptible standard.
Means followed by the same letter(s) are not significantly different.

## Host resistance to coffee leaf rust

It is believed that coffee leaf rust has been occurring in Ethiopia for a long period with limited epidemic proportion, probably because of their coexistence, the genetic heterogeneity of coffee population, and the wide level of resistance. Several coffee expeditions were earlier made to collect cultivated or spontaneous Arabica coffee types in Ethiopia with the purpose of searching for new sources of resistance to the coffee leaf rust. Among others Kaffa, Teferi-Kela, Ennaria types were found quite productive and resistant to the rust in India, others such as Dalle, Dilla and Jimma types were resistant in Kenya (Eskes, 1989). Meseret *et al*. (1987) collected and screened about 975 coffee germplasms for their reaction to the physiologic races of *H. vastatrix* and identified eight host reaction groups namely E, C, alpha, beta, D, J, L, and W. The E group ($SH_5$) comprised 65.6% of the collections and had a narrow genetic base with susceptibility to 23 rust races known to attack coffee. The C group ($SH_1SH_5$) was the second largest (24%), widely distributed in Kaffa and Illubabor. The L-group (Ghimbi) was resistant to all Ethiopian races and the 30 out of 32 *H. vastatrix* races of the world (Table 16).

The previously released CBD resistant selections possessed moderate resistance to rust (Van der Graaff, 1981; Merdassa, 1986; Meseret, 1991; 1996). Nevertheless high rust severity was observed on some selections in large-scale coffee plantations at Teppi and Bebeka due to the extensive occurrence of genetically uniform host populations constituting ideal medium for infection or shift in race of the fungus (Meseret, 1996; Eshetu *et al*., 2000b).

The classical leaf disc technique suggested by Merdassa (1986) was found to be unsuccessful in screening for resistance to leaf rust and was replaced by seedling inoculation test in the glasshouse. Coffee seedlings of promising progenies inoculated with field collected rust inoculum by brushing newly expanded true leaves (Girma and Chala, 2008). Girma and Chala (2008) indicated that coffee lines 2179 (Catimor J-21), Catuai and 8136 had no rust infection; while lines 1579, 7455, 74139, 7516 and 3670 revealed moderate

infections of less than 30% in the seedling test. Hence, Catimor J-21 and 8136 were recommended for large-scale production, the former in low altitude coffee growing areas where CLR is prevalent.

Table 16. Composition and distribution of *Hemileia vastatrix* physiologic groups identified from coffee germplasm collected in Ethiopia (after Meseret *et al.*, 1987).

.

| Administrative regions | Accessions tested (n) | Physiologic groups and host genes for resistance[1] | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | E | C | Beta | Alpha | D | J | W | L |
| Keffa | 199 | 123 | 54 | 6 | 7 | 0 | 6 | 3 | 0 |
| Illubabor | 104 | 53 | 45 | 2 | 4 | 0 | 0 | 0 | 0 |
| Wollega | 72 | 49 | 18 | 1 | 1 | 4 | 0 | 0 | 1 |
| Gamo Gofa | 38 | 18 | 5 | 13 | 2 | 0 | 0 | 0 | 0 |
| Sidamo | 325 | 219 | 87 | 8 | 3 | 7 | 1 | 0 | 0 |
| Shewa | 69 | 46 | 8 | 14 | 1 | 0 | 0 | 0 | 0 |
| Hararge | 141 | 120 | 17 | 1 | 3 | 0 | 0 | 0 | 0 |
| Gojam | 27 | 14 | 0 | 13 | 0 | 0 | 0 | 0 | 0 |
| Total | 975 | 640 | 234 | 58 | 21 | 11 | 7 | 3 | 1 |
| Percent (%) | 100 | 65.6 | 24.0 | 6.0 | 2.2 | 1.1 | 0.7 | 0.3 | 0.1 |
| No of virulent races in each group | | 23 | 6 | 30 | 8 | 11 | 7 | 3 | 4 |

[1] E = ($SH_5$), C = ($SH_1SH_5$), Beta = ($SH_2$), Alpha = ($SH_1$), D = ($SH_2SH_5$), J = ($SH_4SH_5$), W = ($SH_1SH_4SH_5$), L = ($SH_1SH_2SH_5$).

# Chemical control

## Chemical control of CBD and leaf rust

Studies on chemical control of CBD started a year after the disease outbreak in Ethiopia in 1971, and results of the trials conducted until 1985 were reported by Merdassa (1986). More than 20 different fungicides were tested in the field between 1987 and 1997 at Gera. Of these, six products that showed consistently superior in controlling the disease and increasing coffee yields for at least three seasons were recommended for use (Table 17) (Eshetu *et al.*, 2000a). The two copper-based fungicides, Nordox (Cuprous oxide) and Octave Super and tank mixture of Chlorothalonil and Cuprous oxide were recommended for CLR and CBD control in areas where both diseases occur concurrently (Eshetu *et al.*, 2000a). Based on the disease epidemiology and berry development, time and frequency of fungicide applications were determined. Spray schedule should start at 'pin' head stage of the berries (6 weeks after main flowering) and continue thereafter at 4 weeks interval for at least 6 rounds in order to protect the developing berries from infection. High volume sprays varying from 750 to 1000 ml/tree (depending on size and canopy) by hand-operated knapsack sprayers until run-off is recommended in areas where water supply is not a problem. Application of about 200 ml/tree using motorized knapsack sprayer

was recommended in areas where water is in short supply (Merdassa, 1986; Eshetu *et al.*, 2000a).

Table 17. Recommended fungicides for the control of CBD in Ethiopia (after Eshetu, *et.al.* 2000).

| Fungicides | | Formulations[1] | Rate (kg/ha) |
|---|---|---|---|
| **Common names** | **Trade names** | | |
| Chlorothalonil | Daconil 2787 | 75 % WP | 4.4 |
| Chlorothalonil | Daconil | 75 % WDG | 4.4 |
| Fluazinam | Shirlan | 50 % SC | 1.1 |
| Cuprous oxide | Nordox | 50 % WP | 7.7 |
| Prochloraz/copper | Octave super | 50 % WP | 6.5 |
| Chlorothalonil<br>+[2]<br>Cuprous oxide | Daconil 2787<br>+<br>Nordox | 75 % WP<br>+<br>50 % WP | 2.2<br>+<br>5.5 |

[1] FW= flowable, SC= suspension concentrate, WP= wettable powder, WDG= wettable dispersible granule; [2] a tank mixture of both products.

## Coffee wilt management

Unlike CBD, coffee trees infected by the CWD pathogen cannot be cured any more, hence, successful control of the disease should be based on the principles of disease prevention (avoid wounding of any part of the plant) and phytosanitation. A preliminary results of both on-station and on-farm trials implicated that coffee stem paint with copper fungicide such as Kocide reduced CWD incidence. In addition, applying mulch, ash, and hand weeding around coffee trees were promising treatments (Fig. 4) (CABI, unpublished data). Painting saw-cut surface of stumped coffee with this product was observed to protect the large wound surface effectively from infection. Moreover, disinfection of farm implements such as machetes, bow-sow and pruning shears with potent alcohol (> 75 %) followed by heating with fire are strongly advised to coffee farmers whenever slashing, pruning and rejuvenating old coffee trees are practiced. In addition, uprooting and burning of infected coffee trees at the spot must be practiced at the earliest symptom appearance and replanting with coffee seedlings should be delayed at least for 2 years (Girma *et al.*, 2001; Girma, 2004).

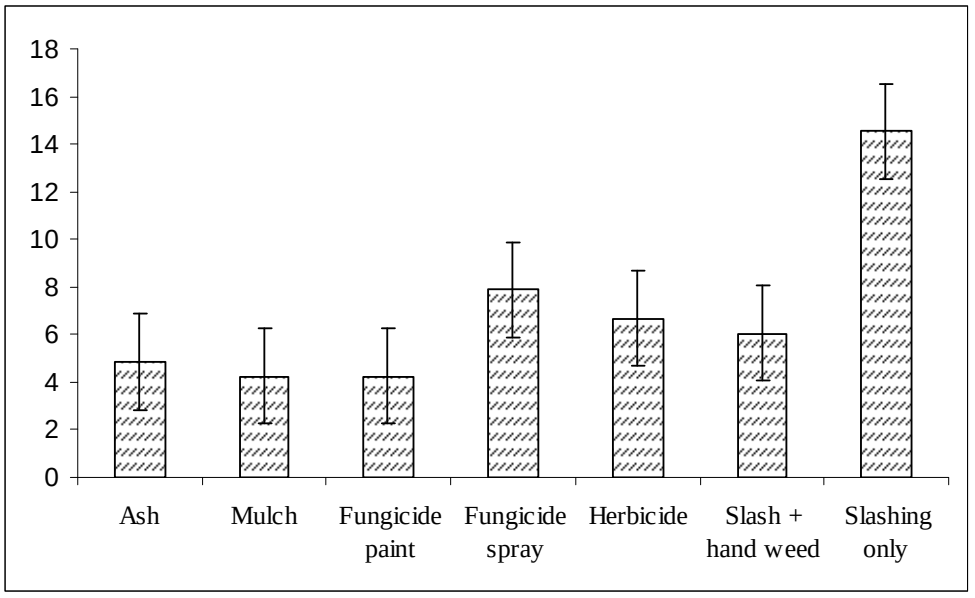


Fig. 4. Effect of different agronomic practices and control methods on the incidence of CWD in Ethiopia (bars show standard deviations) (after CABI, unpublished data).

# Conclusion and recommendations

## CBD management

### 1. Adoption of CBD resistant selections

In addition to the 15 released cultivars, more than 8 highly resistant selections viz. 7418, 74153, 7514, 7516, 7576, 75129, and 8136 were identified, verified and recently recommended for production in south west Ethiopia.

### 2. Safe use of recommended fungicides

Those locally tested and approved fungicides should be applied to susceptible coffee trees until location specific adaptable CBD resistant and high yielding landraces will be made available to farmers. Use of unauthorized/smuggled and expired products and incomplete spray schedules should be avoided. Coffee farmers should regularly be advised on safety measures thereby reduce ill effects of pesticides to man and the environment.

### 3. Cultural control

Removal of CBD infected mummified berries from the tree and fallen berries from the ground reduce the major sources of primary inoculum in the succeeding cropping season. Pruning and removing unproductive

suckers and verticals will ventilate and create unfavorable condition for the pathogen infection (improve microclimate within coffee trees).

### 4. Apply disease escape mechanism

Inducing early flowering of coffee trees hasten berry development so that the susceptible stage of berries escape CBD outbreak in irrigable areas. Also avoid planting susceptible materials in valley-bottoms where the conditions are favorable for the disease.

## Coffee wilt management

### 1. Phytosanitary measures

These practices should be taken seriously into account as strict surveillances of fields, uprooting and burning of infected coffee trees with typical wilting symptoms, before the fungus produce perithecia and ascospores.

### 2. Prevent wounding of any part of coffee trees

Cultural weed control practices such as slashing and digging of coffee fields should be avoided or be practiced with great care in order to avoid wounding the tree, and hand weeding around coffee trees, or spraying herbicides, application of mulch and growing cover crops such as *Desmodium* spp. are recommended. Agronomic practices, which involve regular pruning and stumping of unproductive coffee trees that bring about wounding of the trees, should be done with efficiently disinfected tools.

## Coffee leaf rust management

1. Adjust cropping system through growing mixed/ heterogeneous coffee populations
2. Avoid planting rust susceptible coffee types like Harar coffee particularly at lower altitudes (< 1500 m)
3. It is advisable to spray cupper based fungicides in cases of severe leaf rust outbreak

## Gaps and challenges

There is always shift in the status of diseases because of selection pressure imposed by planting new coffee varieties and improving practices from traditional to modern production systems. There would also be alteration in the host-pathogen-environment interactions and resurgence in the existing populations or introduction of new pathogen owing to poor quarantine both at national and international levels.

CBD is still the leading disease of Arabica coffee significantly affecting yield in all coffee growing regions of the country, while more than 90% of the coffee population is vulnerable to CBD. On the other hand, chemical control is constrained by lack of subsidy for fungicide and sprayer purchase; and above all challenged by the present tendency towards organic coffee production. CBD is more severe in highlands. In lowlands, it occurs when the weather is favorable for it to attack moderately resistant cultivars and hybrids. It has been experienced that a moderately resistant coffee variety known as 'Dessu' (F59) succumb to CBD at middle altitudes areas (1750 m) during the years with favourable weather conditions. Arega (2006) recorded up to 40% CBD incidence in forest coffee populations in lowland areas of Bonga, Bale, Sheko and Yayu (< 1500 m). CBD pathogen isolates collected from these localities were proved as aggressive as those isolates obtained from highlands of Gera. Therefore, recommending less tolerant but high yielding pure lines and hybrids based merely on altitudinal domain is rather challenging.

The inheritance mechanism of CBD resistance is known to be governed by recessive genes and exploitation of hybrids possessing resistant trait and high yield needs repeated and painstaking backcrossing activities. Furthermore, large-scale multiplication of hybrid coffee via seeds is perhaps tedious and propagation by cutting and tissue culture techniques seems expensive. Thus, development of CBD resistant cultivars through selections and intensive testing of mother trees and their progenies from each landrace populations are indisputable. Besides, selecting resistant cultivars from one specific locality and introducing into new coffee growing areas has a number of drawbacks. The adaptation problems as practically realized in Hararghe, genetic erosion and/or mix up of potential landraces in terms of valuable traits for quality, yield and disease/insect pest resistance have their own biodiversity and market brand risks. Harar coffee, for instance, is highly susceptible to most diseases including CBD, although it is known to fetch premium price for its best quality profile, nevertheless farmers prefer growing alternative cash crop Chat (*Catha edulis*) to planting coffee.

Like any other soil borne diseases, coffee wilt disease management is also troublesome by virtue of being vascular nature of the pathogen and the difficulties of conventional control approach (uproot and burn infected trees at the spot!). The disease epidemiology is less understood. Coffee management /agronomic practices such as slashing and/or hoeing, pruning activities aggravate the disease situation in various ways. The use of infected trees for fire wood, staking/pegging, constructing huts and fencing purposes and immediate replanting of coffee seedlings have been observed to further disseminate and build up the fungus inoculum (Girma *et al.*, 2001; CABI, 2003). Although strong efforts have been made to aware and train coffee

farmers about CWD management through practical training of extension workers, publicity materials (manual, brochure, leaflets, and mass media); little achievement has been made to contain coffee wilt in Ethiopia.

Coffee leaf rust, the number one disease in other coffee growing countries, is of minor concern in semi-forest and forest coffee systems of Ethiopia, but it demands due attention in the garden and plantation coffees. In general, rust pathogens are so dynamic in nature and hitherto more than 40 physiologic races have been recorded in the world (Prakash *et al*., 2007). Because of lack of differential coffee groups, information is incomplete or lacking on the current race spectra in the country. The host, pathogen, hyperparasites and environment interactions in the forest and semi-forest conditions have been more of speculation.

## Prospects

Coffee berry disease management by growing resistant cultivars leads to sustainable, environmentally-friendly organic coffee that fetch premium price, thus primarily developing resistant coffee cultivars for each ecological niche in the major coffee growing regions of the country should get the highest priority. This strategic approach will enable to maintain ecologically adapted coffee landraces securing undiluted quality profile of special interest (specialty coffee) in the world market. Secondly, effective and selective fungicides should continuously be screened and made available to coffee farmers at affordable price. Thirdly, biopesticides derived from microbial agents and botanical extracts against CBD pathogen needs to be investigated. The 'CBD escape' mechanism through changing the cropping pattern by using irrigation and inducing early flowering and berry growth before disease outbreak in a season should be exploited. Moreover, farmers' indigenous knowledge need to be explored; and ultimately all practices should be incorporated to develop integrated disease management (IDM) program in coffee.

The prospects of successful control of coffee wilt rely principally upon employing resistant coffee cultivars and adopting stringent prophylactic measures. In this regard, full-fledged independent selection program should be envisaged hand-in-hand with screening all the promising CBD resistant selections for resistance to CWD. Re-inoculating grown seedlings (10 – 12 months) in lathhouse should further prove the host resistance. Understanding the gene(s) that govern resistance to CWD and inheritance mechanisms of the resistance is of paramount importance to design and implement effective breeding program. In addition, biocontrol agents including *Trichoderma* spp. should be worked out as for other *Fusarium* pathogens. More efforts should be

made to aware and sensitize all stakeholders with available update information on CWD managements.

Regarding coffee leaf rust, physiologic races of the fungus populations across various coffee areas should be detected and timely updated by introducing and establishing standard differential coffee lines. This avoids testing for resistance with randomly collected rust isolates of unknown physiologic race (s) thereby strengthen screening and identifying rust resistant coffee cultivars. Furthermore, the biology, epidemiology, alternate hosts, and the hyperparasites interrelationships should be studied in detail. The potential role of hyperparasites as biocontrol agent should be assessed and investigated. The dynamics of sporadically occurring diseases of coffee should regularly be monitored.

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# Review of Research on Diseases of Fiber Crops in Ethiopia

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## Introduction

Crops grown for fiber production in Ethiopia are cotton, kenaf, and sisal. Of these, only cotton has wider adaptation, deep-rooted culture, and economic importance. Cotton is one of the major cash crops in Ethiopia, earning foreign exchange from export of lint and finished fabrics and serves as raw material for the cottage industry. Mesfin (1982) reported that the highest amount of cotton is produced in the Awash Valley and in the northwestern part of the country, while a negligible amount is produced in the southern part. The production of sisal attained its peak in the 1960s and 1970s and started to decline in the early 1990s. Currently, it is not easy to know where it is being produced and how much area is allotted to its production. Kenaf is an important stem fiber crop. Kenaf fiber is used to make rope, cordage, nets, sacks, bags and canvas (IAR, 1986). Ethiopia imports large quantities of kenaf fiber to satisfy local mill needs and spend more than 15 million Birr per annum (Asfaw, 1985). According to Asfaw (1985) and Asfaw and Mesfin (1985), kenaf research in Ethiopia began in the late 1970s and early 1980s with a few introduced genotypes. The crop was produced in only small areas in the former state farms of Birr, Beles and Ukie (Asfaw, 1985; Asfaw and Mesfin, 1985; IAR 1988), and on experimental plots at Werer.

Unlike in other parts of the world, cotton is attacked by a few diseases in Ethiopia. In the past, bacterial blight and wilt diseases were considered to be the most important, but since the last one decade these diseases are recorded to be less important countrywide. However, bacterial blight is still the most important disease on cotton grown in wet and humid areas of the country. Moreover, an unidentified wilt disease (locally known as *Dubti syndrome*) was important in irrigated cotton at Dubti. On kenaf, root knot-nematodes, collar rot and stem rot are known to be important diseases. Information on diseases attacking jute and sisal is lacking in the country.

# Research findings

## Diseases recorded on cotton

Surveys conducted since 1985 in different cotton growing areas of the country revealed numerous diseases (Table 1). Of these, bacterial blight, which occurs in very moist climatic conditions, usually during prolonged rains in the West and northeastern parts of the country, and wilt at Tendaho are considered important (Geremew, 1990).

Table 1. List of cotton diseases recorded in Ethiopia.

| Common name | Pathogen | Status | Reference |
|---|---|---|---|
| Bacterial blight (on leaf) | *Xanthomonas campestris pv. malvacearum* | major | 2, 5, 6, 13, 18 |
| Angular leaf spot (on leaf) | *X. campestris pv. malvacearum* | major | 2, 5, 6, 13 |
| Black arm (on stem and petiole) | *X. campestris pv. malvacearum* | major | 2, 5, 13 |
| Dubti syndrome | Unidentified | major | 2, 6 |
| Verticillium wilt | Verticillium dahliae | minor | 2 |
| Fusarium wilt, root rot | Fusarium oxysporum f. sp.vasinfectum | major | 13 |
| Leaf spot | *Alternaria macrospora* | minor | 3, 13 |
| Leaf spot | *Phyllosticta malkoffi* | minor | 3, 13 |
| White leaf spot, mildew | *Ramularia gossypii* (Speg.) Cif. | minor | 3 |
| Leaf blight | *Ascochyta gossypii* | minor | 13 |
| Leaf blight | *Cercospora gossypina* | minor | 13 |
| Rust | *Phakopsora gossypii* | minor | 3 |
| Powdery mildew | *Leveillula* sp. | minor | 3, 13, 18 |
| Anthracnose, damping off | *Colletotrichum gossypii* | minor | 3 |
| Root rot | *Sclerotium rolfsii* | minor | 6 |
| Root rot | *Sclerotium bataticola,* | minor | 6 |
| Root rot | *Fusarium solani* | minor | 6 |
| Root rot | *Rhizoctonia solani* | minor | 6 |
| Root-knot nematode | *Meloidogyne incognita* | rare | 2, 5, 6 |
| Nematode | *Dorylaimus* sp. | rare | 2, 6 |
| Nematode | *Heterodera* sp. | rare | 2, 6 |
| Nematode | *Rotylenchus* sp. | rare | 2, 6 |
| Boll rot, damping off | *Rhizoctonia solani* | minor | 3, 7 |
| Boll rot | *Fusarium acuminatum* | minor | 3, 7 |
| Boll rot | *Phytophthora capsci* | minor | 3, 7 |
| Boll rot | *Xanthomonas campestris* | minor | 3, 7 |
| Boll rot, damping off | *Colletotrichum* sp. | minor | 3, 7 |
| Boll rot | *Acremonium* sp. | minor | 3, 7 |
| Boll rot | *Aspergillus* sp. | minor | 3,7 |
| Boll rot | *Neurospora* sp. | minor | 3, 7 |

Table 1. Contd.

| Common name | Pathogen | Status | Reference |
|---|---|---|---|
| Damping off | *Fusarium* sp. | minor | 6 |
| Damping off | *Pythium* sp. | minor | 6 |
| Sooty molds | *Aspergillus flavus* | minor | 2, 3, 7 |
| Sooty molds | *Aspergillus niger* | minor | 2, 3, 7 |
| Anthocyanosis or cotton blue | Suspected viruses | rare | G |
| Mosaic | Suspected cotton mosaic virus | rare | G |
| Leaf curl | Suspected cotton leaf curl virus | sporadic | 13 |

G = Geremew pes. Observation.

# Disease control

## Cotton resistance to bacterial blight

Bacterial blight was severe on irrigated cotton in the Middle Awash in the late 1960s. It caused losses ranging from stand and vigor losses of seedlings to total crop failure. However, heavy yield losses were attributed to leaf blight (which caused leaf defoliation) and blackarm (which caused losses of fruiting branches) (IAR, 1983). With the introduction of resistant cotton varieties such as Acala 1517/70 in the late 1970s the significance of bacterial blight declined in irrigated cotton, although it remained a problem in high rainfall and humid areas such as Pawe and Gambella (MWRC, 1997). Therefore, trials on screening of cotton genotypes for resistance to the disease were undertaken at Pawe from 1996 to 1998, and differences among the genotypes ranged from moderately resistant to highly susceptible. Many *G. hirsutum* varieties of cotton known for their resistance or tolerance to the disease in other parts of the country were found to be susceptible at Pawe. Other diseases were reported to be sporadic and of minor importance that no screening of varieties was initiated.

# Basic studies

## Pathogenecity test

*Colletotricum gossypii*, the pathogen that causes anthracnose was isolated and inoculated in two commercial varieties of cotton (Deltapine 90 and Acala SJ2) both at seedling and flowering stages under field conditions at Werer and in the greenhouse at Holetta during the 1990/91 cropping season. All of the seedlings developed specific disease symptoms, while inoculation at flowering resulted in only 60% infection. It was therefore concluded that anthracnose could be a severe disease when infection occurs at the seedling stage. Since then, however, the incidence of anthracnose on cotton declined (IAR, 1996).

### Wilt diseases

Cotton wilt diseases are caused by two soil-borne vascular pathogens, *Verticillium dahliae* and *fusarium oxysporum.* The diseases are known to occur occasionally in Tendaho, less frequently in Arbaminch and sporadically in the Middle Awash cotton farms. Verticillium wilt is recorded only from Sile farm (Semen Omo Agricultural Development Enterprise), while fusarium wilt was common in most farms of the Middle Awash and rain-fed cotton (Geremew, 1990).

## Studies on the cause of *Dubti syndrome*

### Plant tissue analysis

The cotton wilt that occurs at Tendaho is called *Dubti syndrome*. In the efforts to identify the causal pathogen(s) experts from different countries in the world (United Kingdom, Germany, Yemen, and India) were involved and over 2000 isolations were prepared from the plant tissues from which *Sclerotium bataticola*, *Fusarium solani*, *Rhizoctonia*, *Aspergillus*, *Rhizopus, Penicillium* species, and other weak soil fungi were identified. However, none of these fungal isolates induced similar disease symptom on inoculated plants under controlled conditions (Geremew, 1992).

### Soil assessment

From 1988 to 1990 soil assessment study was conducted for microsclerotia of *Verticillium dahliae* and *Fusarium* sp. Soil samples were taken from three depths (0-30, 31-60, 61-90 cm) at Dubti, Asaita, Senbeleta, Detbahry and Tangayekuma from the lower and Ambash from middle Awash areas. Samples were cultured on four different growth media (PDA, PDA with streptomycin, Zchapek Dox Agar and Zchapek Dox liquid medium) under diffused light and total darkness at 24 $\pm$ 2$^{o}$C. After 7 days of incubation only saprophytic fungi, such as *Aspergillus* sp. were identified. Thus, it was concluded that the disease is non-pathogenic (IAR, 1996).

### Effect of temperature on wilt development

To study the impact of air temperature on wilt development, meteorological data of more than 20 years was obtained from the Dubti and Werer stations. Cotton production years were divided into wilt and non-wilt years. On years with wilt incidence, night temperatures in October and November were between 10 and 13.5$^{0}$C, but in non-wilt years it ranged from 13 to 15$^{0}$C. The slight difference (1.5$^{0}$C) in the minimum temperature between wilt and non-wilt years suggested that the Dubti Syndrome was not associated with temperature changes (Geremew, 1992).

## Effect of soil pH on cotton wilt development

The soil pH at Tendaho was alarmingly changed from 7.6 to 8.4, and this was related to the wilt problem (Steven, 1974 pers. com.). Studies conducted at three fields in each of three farms, Melka Sadi, Melka Werer and Ambash in 1992 indicated that high pH was not a factor in wilt development (Geremew, 1992).

## Loss assessment

Cotton yield losses caused by wilt diseases are reported to vary with years and locations. At Tendaho up to 90% of the cotton plants in some fields were wilted, while at the middle Awash (Melka Sadi and Ambash farms the percentages of wilted plants were 1-2% in 1987 and 3-5% in 1992. As the diseases appeared late in the season, in most cases after the third to fourth irrigation periods, losses in lint yield were minimal (Geremew, 1992). However, quality losses, especially maturity ratio, fiber strength, and fineness could be much higher than physical yield. A study conducted in 2004 with a cotton variety Deltapine 90 at Melka Sadi showed a yield loss of 76%. Differences between healthy and diseased plants in boll number, boll weight per plant and seed number per boll were observed to be 74.62, 12.96 and 13.28%, respectively (Table 3) (Geremew, unpublished data).

## New disease recorded

An unknown disease was observed on cotton plants at the Nura Era and Awara Melka farms of the Upper Awash Agro-industry Enterprise in 2001 and 2002. Diseased plants had abnormal leaf morphology (i.e. pointed, leathery and hard) and root swelling just bellow the ground surface expressed the disease symptom. Flowers and squares could not open normally and changed to capsules. The disease was named Nura Era syndrome, and later identified to be caused by *Agrobacterium* sp. However, this identification is still to be confirmed. The disease occurred in about 60 ha of land and affected all plants in the field uniformly. Bacterial diseases are known to spread slowly and do not infect all plants in a plot at least at once like this disease. It is from this contention that it is less probable for *Agrobacterium* sp. to be the cause for the Nura Era syndrome.

## Diseases of kenaf

List of diseases recorded on kenaf in Ethiopia are presented in Table 2. The root knot nematodes caused by *Meloidogyne incognita* and *M. arenaria*, crown and collar rots caused by *Colletotrichum capsici* and stem rot caused by *Botrytis cinerea* were reported to be important. Asfaw and Mesfin (1985), IAR (1987) and Geremew (1992) reported that only the root knot nematodes followed by stem discoloration were of major importance.

Table 2. List of kenaf diseases recorded in Ethiopia.

| Common name | Pathogen | Status | Reference |
|---|---|---|---|
| Stem rot | *Botrytis cinerea* | major | 3, 9 |
| Crwn rot | *Colletotrichum capsci* | major | 3, 9 |
| Collar rot | *Phoma* sp. | major | 3, 9 |
| Leaf spot | *Didymella sp.* | minor | 3 |
| Leaf spot | *Leptosphaerulina trifolii* | minor | 3 |
| Leaf spot | *Phoma ibiscola* | minor | 3 |
| Leaf blight | *Ascochyta gossypii* | minor | 13 |
| Leaf blight | *Cercospora gossypina* | minor | 13 |
| Anthracnose | *Colletotrichum capsci* | minor | 3 |
| Anthracnose | *Colletotrichum gossypii* | minor | 3 |
| Root rot | *Sclerotium rolfsii* | minor | 9 |
| Root rot | *Sclerotium bataticola* | minor | 9 |
| Root rot | *Fusarium oxysporum* | minor | 9 |
| Root rot | *Fusarium solani* | minor | 9 |
| Root rot | *Rhizoctonia solani* | minor | 9 |
| Root-knot nematode | *Meloidogyne incognita* | major | 3, 9 |
| Root-knot nematode | *Meloidogyne arenaria* | major | 3, 9 |
| Root-knot nematode | *Heterodera* sp. | rare | 3, 9 |
| Root-knot nematode | *Rotylenchus* sp. | rare | 3, 9 |
| Root-knot nematode | *Dorylaimus* sp. | rare | 3, 9 |

## Yield loss assessment

Studies conducted at Werer and Didessa from 1982 to 1984 indicated a dry matter loss of 29.3% on the average (Table 3) (Mesfin, 1984; Asfaw, 1985; Asfaw and Mesfin, 1985).

Table 3**.** Yield **l**osses in cotton and kenaf.

| Crop | Diseases | Damaged parts | Percentage of losses | | References |
|---|---|---|---|---|---|
| | | | Range | Mean | |
| Cotton | Wilt | Seed cotton yield | 0.062-76.04 | 38.05 | 4 |
| | | Boll No. | - | 74.62 | |
| | | Boll weight | - | 12.96 | |
| | | Seed No. | - | 13.28 | |
| | | Fiber length | - | 2.03 | |
| Kenaf | Root-knot nematode | Fiber yield | 14.4 - 54.2 | 29.3 | 1, 17 |

### Variety screening

Twenty seven kenaf genotypes evaluated for resistance to the root knot nematodes at the Werer Research Center from 1982 to 1985 showed that genotypes MT-18, Nourongo, Everglades 41, and Ix-49 had disease intensity rates of 2.4, 2.5, 2.5, and 2.93, respectively, on a 0-9 rating scale (Asfaw, 1985; Asfaw and Mesfin, 1985). The overall mean ranged between 2.03 and 4.01 (IAR 1987).

## Conclusion and recommendations

- In order to minimize the spread of wilt and bacterial blight diseases of cotton, use of seeds obtained from disease free area or acid delinted/ steeped in 1% formaldehyde solution for 20 minutes is recommended
- In blight and wilt prone areas high plant population (over 60,000 plants/ha) is recommended; fields should be furrow irrigated and the standing water must be drained from the field to minimize humidity in the canopy
- Cotton is a sensitive crop to temperature changes especially in the night during squaring and flowering, thus areas for cotton production should have an average temperature of not less than $18^{o}$C and soil pH ranging from 7-8
- Proper and timely scouting and effective control of insect vectors (aphids, jassids, thrips, and whiteflies) involved in the transmission of virus diseases is important
- In areas with root knot nematode infestations, use of less susceptible kenaf varieties such as MT-18, Nourongo, Everglades 41, IX-19 and IX-49 should be planted

## Gaps and challenges

- The causal agent for the Dubti syndrome is not identified to date (the assumption that it is caused by a toxin (hydrogen sulphide) should be confirmed
- Viral diseases of cotton received inadequate attention mainly due to shortage of human power and laboratory facilities
- Lack of resistance for bacterial blight in high rainfall areas is an open ended challenge for breeders and pathologists. Seedling, boll, leaf and stem diseases of cotton are totally untouched and thus need due attention, although their current status is minor

- The problems of root-knot nematodes and collar rot diseases needs detail studies, if kenaf is to be considered for commercial production in the future

## Prospects

- Viral diseases are potential threats for the cotton industry. Thus, systematic and continuous surveys should be launched, virus diseases should be identified, documented, their etiology should be studied, losses quantified and their spread should be contained.
- The necessary human power should be recruited; and laboratory facilities should be fulfilled
- The cotton breeding program should give emphasis to the development of disease resistant varieties, especially resistant to bacterial blight for rain-fed areas of the country.
- Studies on cultural control of cotton diseases should be developed and integrated with other options
- The problem of collar rot disease of kenaf and root-knot nematodes should be addressed and resistant kenaf varieties be developed

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# Review of Weed Research on Root and Tuber Crops

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## Introduction

More than 10 million people in Ethiopia depend on root and tuber crops as their major or supplementary food. The crops are also valued for their great yield potential per unit area. Root and tuber crops are attaining increased importance in southern, southwestern, western, and central parts of Ethiopia. Enset (*Musa* sp.), sweet potato (*Ipomea batatas*), Irish potato (*Solanum tuberosum L.*), cassava, yam and taro are widely grown in the country. Among these crops, enset is endemic to Ethiopia and is widely cultivated. The total area under enset in Ethiopia is about 224,400 hectares. The area occupied by the crop in the Southern Nations Nationalities and Peoples Region (SNNPR) and Oromia Regional State is 145,860 and 78,600 hectares, respectively (CSA, 1994). Currently, enset is used as a staple food supporting about 7-10 million people in the southern part of Ethiopia and its utilization is expanding to other parts of the country. However, the management practices remained traditional and not much effort was made to improve them.

Sweet potato is one of the most important root crops grown in Ethiopia. The exact time of introduction of the crop to the country is not known. However, the crop has been part of the traditional farming systems for centuries, particularly in the densely populated areas of the south, southwestern and eastern parts of the country. It is grown principally for its root, which is used for food, feed and source of starch. In addition to its excellent nutritional value, sweet potato is remarkable for its ability to produce high yields of edible energy in a relatively short growing season. The ability to yield quickly under marginal climatic and soil conditions has contributed to its role as a food security crop in the areas where it is grown. Nationally, sweet potato ranks third in area coverage among the root and tuber crops, following enset and potato, but second following enset in the SNNPR. About 347,573 metric tones of sweet potato were reported to be produced in SNNPR from 30,936 ha of land (CSA, 1994; ARC, 2002). In addition to food and feed sources, sweet potato is also important cash earner to the resource poor farmers in the region. However, the crop is given less

attention by farmers in terms of land allocation, weeding and other management practices.
The Irish potato is grown on a land area of 50,000 hectares in Ethiopia (Tenaw et al., 2001). It is becoming an important food and cash crop for small-scale farmers. However, there was no much research work done in areas of weed control in the crop.

The production of root and tuber crops is constrained by a number of biotic factors including weeds. Thus, the objective of this review paper is to highlight the status of weed research on these crops in Ethiopia since 1985 and indicate the gaps and challenges that need to be addressed to alleviate the problem of weeds.

# Research findings

## Sweet potato

### Weed competition study

The effect of weed competition on sweet potato yield was studied at Awassa and Areka Research Centers for three consecutive years (1988-1990). The extents of yield losses due to uncontrolled weed growth were 99% at Awassa and 91% at Areka (Table 1). Maximum yield of 11.9 t/ha at Awassa and 6.5 t/ha at Areka was obtained from two weedings at 45 and 75 days after transplanting (ARS, 2002).

### Cultural weed control

Effects of canopy structure, plant density and weeding frequency on weed infestation and sweet potato yield was studied for three years (1992-1994) at Areka (OARCU, 1996). The dominant weeds in the area were *Plantago* spp., *Capsella rubella, Guizotia scabra, Ageratum conizoides, Galinsoga parviflora* and *Cyperus* species. Results indicated that sweet potato varieties with spreading canopy structure and wider leaf area suppressed weed infestation and reduced weeding frequency (Table 2). Plant density was negatively associated with weed infestation indicating its role in reducing weed population. Twice weeding reduced weed growth. Overall weed infestation was highly affected by canopy structure, increased plant density and weeding frequency. It was also observed that an increase in sweet potato plant density reduced the number of its branches. However, the root yields of sweet potato varieties increased with increasing plant density. Weeding twice increased the yields of Tis1499 and Koka-6 by 20 and 27%, respectively, whereas significant variation in yield was not observed between weeding frequencies for Tis2498. This indicates that the spreading varieties could be weeded only once or twice, while the erect and

intermediate types need to be weeded twice (Table 3). The overall results suggested that canopy structure and plant density could be considered as important options for reducing weed infestation in sweet potato. Such options could also benefit farmers in saving their time and labor.

Table 1. Effect of weeding frequency on yield of sweet potato at two locations in 1988 to 1990 seasons (after Beyenesh, 1992).

| Treatment | Awassa | | Areka | |
|---|---|---|---|---|
| | Yield (t/ha) | Loss (%) | Yield (t/ha) | Loss (%) |
| No weeding | 0.1e | 99 | 0.6e | 91 |
| Weeded at 25 DAT | 1.5d | 88 | 1.3d | 81 |
| Weeded at 45 DAT | 3.2c | 73 | 2.9c | 55 |
| Weeded at 25 and 45 DAT | 7.1b | 40 | 4.3b | 35 |
| Weeded at 75 DAT | 3.7c | 69 | 2.4c | 63 |
| Weeded at 25 and 75 DAT | 11.7a | 2 | 5.8a | 12 |
| Weeded at 45 and 75 DAT | 11.9a | 0 | 6.5a | 0 |
| LSD (5%) | 2.7 | | 2.3 | |
| CV(%) | 26.5 | | 30.0 | |

DAT = days after transplanting

Table 2. Effects of sweet potato varieties on weed infestation (No./$m^2$) at Areka.

| Sweet potato Varieties | Year | | | Mean |
|---|---|---|---|---|
| | 1992 | 1993 | 1994 | |
| Tis 1499 | 183cd | 379a | 205cd | 256a |
| Tis2498 | 153d | 303b | 232c | 229a |
| Koka 6 | 200cd | 363ab | 188cd | 250a |
| Mean | 179b | 348a | 208b | |

Source: Tenaw *et al.*, 2001.

Table 3. Effects of plant density and variety on yield of sweet potato in the 1992 to 1994 seasons at Areka (after Tenaw *et a*l., 2001).

| Plant density (No./ ha) | Variety and yield (t/ha) | | | Mean yield (t/ha) | Percentage of yield increase* |
|---|---|---|---|---|---|
| | Tis 1499 | Tis2498 | Koka 6 | | |
| 50000 | 1.72def | 1.22g | 1.52efg | 1.49b | - |
| 70000 | 2.35ab | 1.37fg | 1.92cd | 1.88a | 26.2 |
| 100000 | 2.62a | 1.29g | 1.84cde | 1.92a | 28.9 |
| 125000 | 2.50ab | 1.15g | 2.17be | 1.94a | 30.2 |
| Mean | 2.30a | 1.26c | 1.86b | | |

* Increase over the least plant density

## Allelopathic effect of sweet potato on weeds

Three sweet potato varieties Tis1449 (early maturing), Ajac (medium maturing) and Awassa 83 (late maturing) were tested for their allelopathic effects on the major weed species of the crop at Awassa Research Center. The three sweet potato varieties were planted in 2000 cropping season. Maize was planted in the 2001/2002 season, after the sweet potato was harvested. Results showed that there was no clear allelopathic effect on both the weeds and the maize. It was concluded that the allelopathic effect of sweet potato might not be expressed within a short period of time (ARS, 2004).

## Enset

Surveys were conducted in enset growing areas of Sidama, Gedio, Kembata, Hadya, Wollayita, and Gurage zones during 1988-1990, and a range of grass and broad leaf weeds were recorded. The dominant weeds were *Snowdenia polystachya, Commelina* spp., *Ageratum conyzoides, Amaranthus* spp., *Bidens pilosa, Guizotia scabra, Tagetes minuta, Cynodon dactylon* and *Digitaria scularum.* It was also observed that special attention is given to enset weeding during June, July and August in many Enset growing areas. Mulching with enset leaves is also practiced to control weeds (CSA, 1997). A one year (1998) result of weeding frequency in Enset at Areka Research Center indicated that plant height and pseudostem circumference were higher with three times weeding in April, July and November. However, the trial was not completed and a clear trend in the weeding frequency could not be observed.

## Irish potato

A study conducted at Bako Research Center indicated that one time weeding between two and four weeks after the emergence of potato plants combined with 2-3 hilling controlled weeds effectively and gave the highest potato tuber yield (Mulugeta and Endale, 1992).

## Common weeds in root and tuber crops

Different species of grass and broad leaved weeds were recorded in different root and tuber crops in southern Ethiopia (Table 4).

Table 4. Common weeds recorded in root and tuber crops in southern Ethiopia (after Stroud and Parker, 1989 and ARC, 2002).

| Family | Species | Common names |
|---|---|---|
| **Amaranthaceae** | *Achyranthus aspera* | Devil's horse whip (E) |
| | *Amaranthus* spp. | Pigweed; spiny pigweed (E) |
| **Capparidaecae** | *Gynandropsis gynandra* | Spider flower (E) |
| **Chengodaceae** | *Chenopodium album* | Fat hen (E) |
| **Compositae** | *Ageratum conyzoides* | Goat weed (E) |
| | *Bidens pilosa* | Blackjack (E) |
| | *Conyza banariensis* | - |
| | *Galisoga parviflora* | Gallant soldier (E) |
| | *Guizotia scabra* | Metch (A) |
| | *Launaea cornuta* | Wild lettuce (E) |
| | *Sonchus asper* | Spiny sow thistle (E) |
| | *Tagetus minuta* | Mexican marigold (E) |
| | *Xanthium stramonium* | Cockle bur (E) |
| **Cyperaceae** | *Cyperus esculantus* | Yellow nut sedge (E) |
| | *Cyperus rotundus* | Purple nut sedge (E) |
| **Euphorbacae** | *Euphorbia hirta* | Asthma weed (E) |
| **Malvaceae** | *Abutilon tiophrestum* | - |
| | *Hibiscus trionum* | Flower in an hour (E) |
| **Plantignacaea** | *Plantago* spp. | Goetteb (A) |
| **Poaceae** | *Cynodon dactylon* | Bermuda grass (E) |
| | *Digitaria scalorum* | Blue couch grass (E) |
| | *Panicum capillare* | - |
| | *Setaria verticillata* | Love grass (E) |
| | *Snowdenia polystachya* | Mudja (A) |
| **Polygonaceae** | *Polygonum nepalense* | Yetija siga (A) |
| | *Portulaca oleraceae* | - |
| | *Rumax abyssinucus* | Dock (E) |
| **Solanaceae** | *Datura stramonium* | Thorn apple (E) |
| | *Nicandra physoloides* | Chinese lantern (E) |
| | *Solanium nigrum* | Black nightshade (E) |
| | *Tribulus terrestris* | Puncture vine (E) |

E= English names, A= Amharic names

Broad-leaved weeds were found to be more dominant than grasses in these crops (Table 5). Moreover, some weeds were found to be more dominant in specific environments. Species such as *Snowdenia polystachya* and *Chenopodium album* were more dominant in fertile soils, while sedges were more dominant in waterlogged areas. Some weeds were more dominant in lowlands others in mid altitudes; some weeds were found to be specific to some crops while others have wide host spectrum.

Table 5. Common weeds in specific root and tuber crops (after ARC, 2002).

| Weed species | Crops infested | Weed species | Crops infested |
|---|---|---|---|
| *Cyperus esculantus* | Taro, potato | *Hibiscus trionum* | cassava |
| *Cyperus rotundus* | Taro, potato | *Polygonum nepalense* | cassava, taro |
| *Digitaria scalorum* | Many crops | *Portulaca oleraceae* | cassava |
| *Cynodon dactylon* | Many crops | *Datura stramonium* | taro, potato, sweet potato |
| *Setaria verticillata* | Cassava | *Nicandra physoloides* | sweet potato, cassava |
| *Panicum capillare* | Many crops | *Solanium nigrum* | sweet potato, taro, potato |
| *Snowdenia polystachya* | Enset, potato, taro | *Tribulus terrestris* | cassava |
| *Amaranthus spp* | Many crops | *Xanthium stramonium* | sweet potato, cassava |
| *Bidens pilosa* | Many crops | *Gynandropsis gynandra* | sweet potato, cassava |
| *Chenopodium album* | Enset, potato, taro | *Conyza banariensis* | cassava, sweet potato |
| *Achyranthus aspera* | Enset, cassava | *Launaea cornuta* | cassava, sweet potato |
| *Galisoga parviflora* | Many crops | *Ageratum conyzoides* | sweet potato, taro, potato |
| *Sonchus asper* | Cassava, enset | *Guizotia scabra* | sweet potato, potato |
| *Tagetus minuta* | Enset, taro | *Rumax abyssinucus* | taro |
| *Euphorbia hirta* | Cassava, taro | *Plantago spp* | taro |
| *Abutilon tiophrestum* | Cassava, sweet potato | | |

# Conclusion and recommendations

Weeds are so often associated with substantial reduction in root and tuber crop yield that their removal should become an integral part of a viable farming system. In sweet potato, weeding at 45 and 75 days after transplanting is recommended for Awasa and Areka areas. The density of weeds in sweet potato was found to be reduced by the canopy structure of the plant and plant density. Therefore, twice weeding is recommended for the erect type, while one weeding is adequate for spreading sweet potato varieties at Areka, Hawsassa and similar areas. The allelopathic effect of sweet potato was not expressed on weeds and maize, probably because time was too short for the phenomenon to be expressed, since the experiment was conducted for only one season. Therefore, the study should be conducted for a longer period to detect the allelopathic effect of sweet potato on other plants.

In enset, the yield losses incurred due to weeds should be quantified and measures should be devised for their control.

In the Irish potato, one time weeding between two and four weeks after emergence combined with 2-3 hilling was recommended for the control of weeds.

Plant population and row spacing may need to be manipulated to make these crops more competitive with weeds. Weed management is only part of the overall crop management system, so any combination of environmental manipulation, crop competition or improved cultural management techniques aimed at reducing weed infestation must be compatible with other components of the farming system.

## Gaps and challenges

Despite the importance of root and tuber crops in this county less research attention is given to these crops in general. Regarding weed problems the following gaps are waiting to be filled urgently: 1) qualitative and quantitative determination of weeds in different agro-ecologies, 2) weed-crop competition studies for determination of economic threshold levels and critical weed-free periods, 3) appropriate cultural and chemical control methods against grass and broad-leaf weeds and development of integrated weed management strategies, 4) appropriate frequency and time of hand weeding, and 5) creation of awareness among farmers about weeds.

## Prospects

The following are some of the points that need to be addressed: 1) qualitative and quantitative weed survey in major root and tuber crop growing areas 2) weed-crop competition studies on major root and tuber crops to determine the economic threshold levels and critical weed-free periods, 3) habitat management studies in order to determine trends and possible shifts in weed infestation due to various management strategy; 5) development of integrated management of weeds in major root and tuber crops, 6) use of competitive crops is one of the most economical methods available to farmers and it will continue to be an increasingly important area of future integrated weed management strategy, 7) awareness creation activities should be done aggressively in order to raise the knowledge of the public about weeds and the problems they cause.

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# Review of Vegetable Crops Weed Research in Ethiopia

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## Introduction

Vegetable crops have a great potential as food as well as export commodities for Ethiopia. The most important vegetable crops grown are onion, tomato, hot pepper, snap bean, cabbage, carrot, beetroot, Swiss chards, and lettuce. Vegetable production has been widely expanding in the Rift Valley and in similar agro ecological regions in the country for its diverse economic benefits as income generating and source of nutrition, source of employment opportunities in the production, marketing and processing chains. Currently vegetables occupy about 129,200 ha with potential yields of 8.9 million tons per year excluding the home gardens in urban and pre-urban centers (Lemma et al., 2008).

Weeds are among the major constraints in the production of these crops in Ethiopia. Vegetable crops are generally more vulnerable to weed competition than agronomic crops because many of them are short-season crops and they are usually weak competitors against weeds. Weed competition in the first four weeks of crop growth can result in severe yield reduction (Etagegnehu et al., 1985a; 1985b; 1989).The extent of yield losses was estimated to be 72, 70 and 94% in onion, tomato and hot pepper, respectively (Etagegnehu et al., 1986a; 1986b; 1986c). In addition to direct losses, weeds can reduce the efficiency of protection against diseases and insect pests thereby lowering quality and marketability, and can cause crop losses by interfering with mechanical and hand harvesting (Etagegnehu et al., 1985b). Weed control has been one of the key cultural practices for better crop production. Since the parasitic weeds (*Orobanche* spp.) are becoming increasingly important in tomato emphasis was given to address the problem. Cultural, physical, chemical, varietal and integrated weed management practices have been carried out on tomato. Only chemical control studies have been carried out on the management of non-parasitic weeds in onion, tomato, and hot pepper. Etagegnehu, et al. (1985b) reviewed weed research conducted between 1979 and 1984 in vegetable crops in this country. However, from 1984 onwards no attempt was made to review

the research findings. Therefore, the objectives of this paper is to review the weed research activities from 1985-2005, asses gaps and set priorities for future weed research on vegetable crops.

# Research findings

## Weeds recorded

Common weeds recorded on some vegetable crops are presented in Table 1. Except *Orobanche* spp., which are specific to tomato, all of the other weed species are common to hot pepper, onion and tomato.

Table 1. Weed species recorded on hot pepper, onion, and tomato in Ethiopia.

| Scientific name | Common name | Status | References |
|---|---|---|---|
| **Amaranthaceae** | | | |
| *Achyranthes aspera* | Devil's horsewhip (E) | x | 14, 22 |
| *Amaranthus hybridus* | Pigweed (E) | xx | 5, 10, 11, 12, 14 |
| *Celosia trigyna* | Belibila (A) | xx | 5, 12, 14 |
| **Boraginaceae** | | | |
| *Heliotroplium cinerascens* | Amangemel (T) | x | 14, 22 |
| *Trichodesma zaylanicum* | Late weed (E) | x | 14, 22 |
| **Capparidaceae** | | | |
| *Gynandropsis gynandra* | Spider flower (E) | xx | 14, 22 |
| **Chenopodiaceae** | | | |
| *Chenopodium opulifolium* | Goosefoot (E) | x | 14, 22 |
| *Chenopodium procerum* | Amedmado (A) | x | 14, 22 |
| **Commelinaceae** | | | |
| *Commelina benghalensis* | Wandering jew (E) | xxx | 5, 10, 11, 12, 14 |
| *Commelina forskalaei* | Wandering Jew (E) | xx | 14, 22 |
| *Commelina latifolia* | Weha aqure (A) | xx | 14, 22 |
| **Compositae** | | | |
| *Ageratum conyzoides* | Goat weed (E) | xx | 5, 12, 14 |
| *Bidens pilosa* | Black lack (E) | xx | 5, 10, 11, 12, 14 |
| *Conyza bonariensis* | Fleabane (E) | x | 5, 12, 14 |
| *Flaveria trinervia* | Clustered yellow (E) | xxx | 5, 10, 11, 12, 14 |
| *Galinsaga parviflora* | Gallant solder (E) | xx | 5, 10, 11, 12, 14 |
| *Guizotia scabra* | Mech (A) | xx | 5, 12, 14 |
| *Launea cornuta* | Wild lettuce (E) | xxx | 2, 5, 10, 11, 12, 14 |
| *Parthenium hysterophorus* | Congress weed (E) | xxx | 4, 15, 16,25, 26 |
| *Tagetes minuta* | Mexican marigold (E) | x | 14, 22 |
| *Xanthium abyssinicum* | Banda (A) | xxx | 2, 5, 10, 11, 12, 14 |
| *Xanthium spinosum* | Spiny cocklebur (E) | x | 14, 22 |

Table 1. Contd.

| Scientific name | Common name | Status | References |
|---|---|---|---|
| **Cruciferae** | | | |
| *Erucastrum arabicum* | Gomen-zer (A) | xx | 5, 10, 11, 12, 14 |
| **Cyperaceae** | | | |
| *Cyperus bulbosus* | Nutsedge (E) | x | 2, 14, 22 |
| *Cyperus esculentus* | Yellow nutsedge (E) | xxx | 2, 5, 10, 11, 12, 14 |
| *Cyperus rotundus* | Purple nutsedge (E) | xxx | 2, 5, 10, 11, 12, 14 |
| **Euphorbiaceae** | | | |
| *Euphorbia heterophylla* | - | xx | 14, 22 |
| *Euphorbia hirta* | Asthma weed (E) | x | 14, 22 |
| *Euphorbia schimperiana* | Anano (O) | x | 14, 22 |
| **Gramineae/poaceae** | | | |
| *Cynodon dactylon* | Bermuda grass (E | xxx | 2, 14, 22 |
| *Digitaria abyssinica* | Couch grass (E) | xxx | 2, 14, 22 |
| *Echinocloa colona* | Jungle grass (E) | xx | 14, 22 |
| *Elusine indica* | Goose grass (E) | xx | 14, 22 |
| *Eragrostis aspera* | - | xx | 5, 10, 11, 12, 14 |
| *Setaria verticillata* | Love grass (E) | xx | 5, 10, 11, 12, 14 |
| *Sorghum arundenaceum* | Johnson grass (E) | xxx | 5, 10, 11, 12, 14 |
| **Labiatae** | | | |
| *Leucas martinicensis* | Bobbin weed (E) | x | 14, 22 |
| **Malvaceae** | | | |
| *Hibiscus trionum* | Flower-of-an-hour (E) | x | 14, 22 |
| **Orobanchaceae** | | | |
| *Orobanche cernua* | Nodding broomrape (E) | xxx | 1,3,5,6,7,14,17,18,24 |
| *Orobanche minor* | Small broomrape (E) | xxx | 3,5,6,14,24 |
| *Orobanche ramosa* | Branched broomrape (E) | xxx | 3,5,6,7,14,17,18,24 |
| **Oxalidaceae** | | | |
| *Oxalis corniculata* | Yellow sorrel (E) | xx | 12, 14 |
| **Papaveraceae** | | | |
| *Argemone mexicana* | Mexican poppy (E) | xxx | 5,10,11,12,14 |
| **Polygonaceae** | | | |
| *Oxygonum sinuatum* | Double thorn (E) | x | 2,5,10,11,12,14 |
| **Portulacaceae** | | | |
| *Portulaca oleracea* | Pursalane (E) | xxx | 2,5,10,11,12,14 |
| **Solanaceae** | | | |
| *Datura stramonium* | Thorn apple (E) | xx | 5,10,11,12,14 |
| *Nicandra physaloides* | Apple of peru (E) | xx | 12,14, 22 |
| *Solanum nigrum* | Black nightshade (E) | xx | 14, 22 |
| **Tiliaceae** | | | |
| *Corchorus olitorius* | - | xx | 14,22 |
| **Zygophyllaceae** | Puncture vine (E) | xxx | 2,5,10,11,12,14 |
| *Tribulus terrestris* | | | |

xxx = major or troublesome weeds, xx = important weeds, x = commonly occurring weeds
E = English, A = Amharic, O = Oromo, T = Tigrigna.

# Control measures

## Host plant resistance

Thirty tomato varieties were evaluated for *Orobanche ramosa* resistance in pots under natural conditions at the Melkassa Research Center (MARC) from 2002-2003. The susceptible variety of tomato Roma VFN was used as a control. Percentage yield loss of tomato due to the weed was used as a main parameter and number and dry weight of *O. ramosa* shoots per tomato plant were used as support parameters. Results revealed that the highest level of resistance was demonstrated in varieties, LE 244, South Africa, CLN 2123 A, Melkashola, Riogrande, Seedathip, LE 180 A, and Cherry with yield losses estimated at 37-45% and numbers of parasite per plant were 7-11. Floradade was found to be highly susceptible. Higher percentage of yield loss (77%) and higher number of parasites (33 shoots/ plant) were recorded (Etagegnehu et al., 2004a; Etagegnehu, 2005).

## Botanical control

A pot experiment was carried out under natural conditions at MARC from 2002-2003. Five plant species (*Datura stramonium*, *Flaveria trinervia*, *Parthenium hysterophorous*, *Tagetes minuta*, *Xanthium abyssinicum*) (wild hosts of broomrapes) and neem were evaluated for their effectiveness against *O. ramosa* in tomato. The results indicated that leaf powder of *Xanthium abyssinicum* strongly interfered with the germination of *O. ramosa* seeds leading to increase in tomato fruit yield. The average number of the parasitic weed per plant was 11. Whereas, powder prepared from *Flaveria trinervia* stimulated the parasitic weed seeds to germinate and increased the number of *O. ramosa* resulting in reduced yield of tomato. The number of parasite per plant was 40 (Etagegnehu, 2005).

# Cultural control

## Trap cropping

Experiments were carried out on tomato on a naturally infested soil with *O. ramosa* and *O. cernua* to test the potential of selected crops in terms of orobanche seed bank exhaustion at MARC, Merti (Upper Awash Agro-Industrial Enterprise) and Ziway (Horticulture Development Enterprise) in 2002 and 2003 (Table 2). In the third season, all plots were planted with a susceptible tomato variety in order to see the cumulative effect of the trap crops. The result indicated that maize and snap bean were better in stimulating germination of the parasitic weed seed by up to 74 and 71%, respectively. Maize and snap bean were compatible and can fit into inter-cropping systems. It was also found that soil seed bank of the *Orobanche* spp. was depleted by

72.5% per season. As a result, the yield of tomato was significantly increased (Ahmed et al., 1988; Girma et al., 2005).

Table 2. Effects of trap crops on *Orobanche* in tomato at different locations.

| Shoot trap crops | Reduction of orobanche (%) | Locations (Shoot count/plot) | | | Mean shoot count/plot | Tomato yield (t/ha) |
|---|---|---|---|---|---|---|
| | | Melkassa | Ziway | Merti | | |
| Fenugreek | 63 | 87 | 89 | 92 | 89 | 61 |
| Linseed | 67 | 78 | 80 | 84 | 81 | 67 |
| Alfalfa | 70 | 76 | 69 | 75 | 73 | 74 |
| Cotton | 66 | 77 | 84 | 86 | 82 | 66 |
| Garlic | 69 | 75 | 74 | 76 | 75 | 71 |
| Onion | 70 | 87 | 73 | 59 | 73 | 75 |
| Pepper | 67 | 88 | 79 | 75 | 81 | 66 |
| Snap bean | 71 | 66 | 76 | 70 | 71 | 78 |
| Maize | 74 | 60 | 62 | 63 | 62 | 85 |
| Sesame | 64 | 90 | 79 | 88 | 86 | 62 |
| Tomato | - | 145 | 235 | 215 | 198 | 42 |
| LSD (0.05) | | 21* | 20* | 16* | 26* | 25* |
| CV (%) | | 10 | 14 | 11 | 12 | 17 |

* = significant

## Fertility management

A pot experiment was conducted to study the effect of various levels of nitrogen, applied as ammonium nitrate, ammonium sulfate, urea, chicken, cow and goat manures on *O. ramosa* infestation at MARC from 2002-2003 dry seasons. The result revealed that parasitism of *O. ramosa* occurred most in untreated and treated pots with low N fertilizer and manure. The average number of *O. ramosa* in the non-fertilized pots was 21. The average number of *O. ramosa* in pots with high fertility was 3-5. Mean shoot dry weight of *O. ramosa* per tomato plant in the untreated pot was high (5.5 g). The mean shoot dry weight of *O. ramosa* per tomato plant ranged from 0.6-1.35 g. in well fertilized pots. Urea at 276 and 207 kg N/ha, ammonium nitrate and ammonium sulfate at 207 kg N/ha and goat manure at 20 and 30 t/ha were found to be effective in reducing parasitism and enhancing growth of tomato plants. High yield 0.65-0.77 kg/plant was obtained from these treatments, whereas 0.15 kg/ plant were obtained from the untreated pot. Although drastic reduction of *O. ramosa* was obtained, ammonium nitrate and ammonium sulfate at 276 kg N/ha seemed to be toxic to the tomato plants. The yield obtained was 0.44-0.47 kg/ plant. However, as nitrogen rates increased the number and dry weight of orobanche shoot decreased and the yield of tomato increased linearly except for the yield obtained from the highest rates of ammonium nitrate and ammonium sulfate (Etagegnehu, 2004b; 2005).

# Physical methods

## Soil solarization

Experiments were conducted to evaluate the effect of soil solarization on Orobanche control in tomato in the central Rift Valley of Ethiopia (MARC, Ziway, and Merti) in the off-season of 2002 and 2003 in fields naturally infested with *O. ramosa* and *O. cernua*. The soil was covered with transparent and black polyethylene sheets of 0.06 and 0.08 mm thick, respectively, and their ability to generate adequate heat to suppress the growth of orobanche was evaluated. It was found that the soil temperature was raised from 32 to 48$^{o}$C, 33 to 46$^{o}$C and 37 to 49 $^{o}$C with the clear polythene sheet at MARC, Ziway and Merti, respectively. Similarly, increases in temperature from 32 to 42$^{o}$C, 30 to 42$^{o}$C and 32 to 41$^{o}$C were recorded with the black polyethylene sheet at Melkassa, Ziway, and Merti, respectively. The reduction of orobanche seeds in the soil due to soil solarization using the clear polyethylene sheet at MARC, Ziway and Merti were 97, 92 and 91%, respectively. The black sheet provided 89, 88 and 86% reduction of orobanche seeds at MARC, Ziway and Merti, respectively. The difference between the two sheets was slight, but the yield of tomato was increased in the plots covered with the clear sheet compared to the uncovered soil (Giref et al., 2005).

## Flooding

Experiments conducted to evaluate the effect of flooding for a prolonged period before transplanting tomato on *Orobanche cernua* at the Nura Era Horticulture Enterprise in 1987 and 1988. The treatments were normal irrigation (at 10 days interval) for two months, flooding first and second month, flooding second month and keeping un-irrigated (dry) for two months. Orobanche shoots emerged were counted at three week interval for three times as shown in Table 3. Results showed significant differences in yield and number of orobanche plants emerged. The lowest number of orobanche (1/m$^2$) was obtained from the first and second month floodings, while the highest number (31/m$^2$) was from plots left dry for two months. Hence, keeping the field flooded and wet can reduce orobanche infestation. However, the yield of tomato was generally low due to the inadequate drainage before planting (Ahmed et al., 1988; Beyenesh el et al., 1992).

Table 3. Effect of soil flooding on Orobanche control in tomato 1987.

| Treatment (before transplanting) | No. of Orobanche/m2 | Tomato | | |
|---|---|---|---|---|
| | | Stand count (No/plot) | Plant height (cm) | Yield (t/ha) |
| Normal irrigation for 2 months | 24 | 54 | 42 | 2.6 |
| Flooding for 2 months | 1 | 54 | 54 | 1.4 |
| Flooding 2nd month only | 10 | 55 | 50 | 0.5 |
| Dry for 2 months | 31 | 53 | 58 | 1.4 |
| LSD | 19 | NS | NS | 0.9 |

# Chemical method

## Onion

Herbicide screening trials have been conducted at Melkassa on onion. Post-emergence herbicides, hand weeding and an unweeded control were compared, and results are shown in Table 4.

Table 4. Effect of herbicides on weed control and yield of onion (1988 and 1989).

| Treatment | Weed control score (1-5) | Phytotoxicity score (1-5) | Yield (q/ha) |
|---|---|---|---|
| Bentazon + propanil 4 l/ha | 3 | 1 | 74 |
| Bentazon + propanil 5 l/ha | 3 | 2 | 96 |
| Bentazon + propanil 6 l/ha | 3 | 2 | 98 |
| Chloroxuron 7 kg/ha | 1 | 1 | 89 |
| Chloroxuron 8 kg/ha | 3 | 1 | 89 |
| Chloroxuron 9 kg/ha | 2 | 1 | 117 |
| Linuron 0.5 kg/ha | 2 | 1 | 94 |
| Linuron 1.5 kg/ha | 3 | 1 | 93 |
| Linuron 2.5 kg/ha | 4 | 1 | 78 |
| Diclafopmethyl 2 l/ha | 2 | 1 | 91 |
| Diclafopmethyl 3 l/ha | 3 | 1 | 94 |
| Diclafopmethyl 4 l/ha | 2 | 1 | 85 |
| Oxyfluorfen 1 l/ha | 2 | 1 | 89 |
| Oxyfluorfen 2 l/ha | 4 | 2 | 133 |
| Oxyfluorfen 3 l/ha | 4 | 2 | 122 |
| Fluazifob-butyl 1 l/ha | 2 | 1 | 104 |
| Fluazifob-butyl 2 l/ha | 3 | 1 | 100 |
| Fluazifob-butyl 3 l/ha | 3 | 1 | 132 |
| Twice hand weeding * | - | - | 119 |
| Unweeded | - | - | 89 |

1 = No effect on weeds and crop, 5 = complete kill of weed and crop

* = 3-8 weeks after transplanting.

The dominant weeds were *Cyperus* spp., *Tribulus terresteris*, *Sorghum arundenanceum*, *Eragrostis aspera*, *Amaranthus hybridus*, *Galinsoga parviflora*, *Commelina benghalensis*, *Launea cornuta*, *Argemone mexicana*, *Portulaca oleracea* and *Datura stramonium*. Oxyfluorfen at 0.47 kg a.i $ha^{-1}$ gave 80% control of weeds as compared with the unweeded check, and it was not phytotoxic to the plants (IAR, 1987; 1988; 1989; Beyenesh *et al*., 1992).

## Tomato

Herbicide screening trial has been conducted at Melkassa on tomato. Four pre-emergence and two post-emergence herbicides, hand weeding and an unweeded check were compared (Table 5). The dominant weeds were *Cyperus* spp., *Tribulus terrestris*, *Sorghum arundenaceum*, *Eragrostis aspera*, *Launea cornuta*, *Datura stramonium*, *Portulaca oleracea*, *Amaranthus hybridus*, *Commelina benghalensis* and *Argemone mexicana*. Metolachlor and bentazon + propanil at 2.88 a.i ha-1 were found to be 85-90% effective to control most of the weeds (IAR, 1987; 1988; 1989; Beyenesh et al., 1992).

Table 5. Effect of herbicides on weed control and injury to tomato (1988-1989 average).

| Treatment | Rate (1.i/ha) | Weed control score (1-5) | Pytotoxicity score (1-5) | Yield (t/ha) |
|---|---|---|---|---|
| Metabromuron +metolachlor | 1.00 l | 4 | 1 | 1.50 |
| Metabromuron +metolachlor | 2.50 l | 4 | 1 | 1.25 |
| Metabromuron +metolachlor | 3.00 l | 5 | 2 | 1.82 |
| Metolachlor | 1.44 l | 3 | 1 | 1.18 |
| Metolachlor | 2.16 l | 4 | 1 | 1.43 |
| Metolachlor | 2.88 l | 5 | 1 | 1.76 |
| Metabromuron | 1.50 l | 4 | 2 | 1.13 |
| Metabromuron | 2.00 l | 4 | 3 | 0.86 |
| Metabromuron | 2.50 l | 5 | 4 | 1.53 |
| Linuron | 0.50 l | 2 | 2 | 1.24 |
| Linuron | 1.00 l | 3 | 1 | 1.26 |
| Linuron | 1.50 l | 5 | 3 | 1.56 |
| Fenxaprepethyl | 0.12 kg | 2 | 1 | 1.26 |
| Fenxaprepethyl | 0.24 kg | 2 | 1 | 1.84 |
| Fenxaprepethyl | 0.36 kg | 3 | 1 | 1.76 |
| Bentazon | 1.92 l | 3 | 1 | 1.28 |
| Bentazon | 2.40 l | 3 | 1 | 1.53 |
| Bentazon | 2.88 l | 5 | 1 | 2.51 |
| Twice hand weeding * | - | - | - | 3.43 |
| Unweeded (control) | - | - | - | 0.61 |
| LSD 5% | | | | 0.8 |
| C.V % | | | | 35.0 |

1 = No control of weeds and no injury to crop, 5 = complete kill of weeds and crop
* = 3-8 weeks after transplanting.

### Hot pepper

One pre-planting and two post-planting herbicides were compared with hand weeding and an unweeded check on hot pepper at MARC in 1999. The dominant weeds recorded in the crop were *Tribulus teresterris, Eragrostis aspera, Datura stramonium, Sorghum arundenanceum, Cyperus* spp., *Galinsoga parviflora, Setaria verticillata, Launea cornuta, Amaranthus hybridus, Commelina bengehalensis* and *Erucastrum arabicum*. Eventhough the pre-planting herbicide metholachlor at 2.16 kg a.i. ha-1 showed promising control of weeds, the pod yield and yield components were not recorded due to severe disease damage.

### Control of *Orobanche cernua* by soil fumigation

Trials were conducted at the Nura-Era Horticultural Enterprise in 1987 and 1988 using Methyl bromide and Dazomet at different rates with and without polyethylene sheet cover on the soil fumigation. The polyethylene cover was sealed all round by means of soil to about 30-40 cm from the edges. Emerged orobanche shoots were counted three times at a three-week interval. Results showed that Methyl bromide under polyethylene sheet cover for seven days can effectively sterilize the soil and control orobanche infestation (Ahmed et al., 1988; 1990; Beyenesh et al., 1992).

### Integrated weed management (IWM)

Experiments were conducted in naturally infested hot spot fields at Nura Era, Melkassa and Ziway to see the interaction of nitrogen fertilizer, herbicide and irrigation frequency on the parasitism of *Orobanche ramosa* in tomato. Significant interaction effects were found in the number of the parasitic weed and tomato fruit yield across locations. Nitrogen fertilizer at 92 kg/ha and irrigation at four days interval gave effective control of orobanche and high tomato fruit yield. Higher fruit yields of 51.2, 58.9 and 53.6 t/ha were obtained from this treatment. Integrated use of nitrogen fertilizer and frequent irrigation appeared to be effective against orobanche. However, further investigations are needed in this regard (Etagegnehu, 2005).

## Conclusion and recommendations

Oxyfluorfen at 0.47 kg a.i.ha$^{-1}$ in onion and metolachlor and bentazon + propanil at 2.88 kg a.i.ha$^{-1}$ in tomato can be used to reduce weeds and improve yield performance. Trap crops such as maize and snap bean could be included in the rotation to reduce orobanche seed in the soil and to increase the yield of tomato. Soil solarization using clear polyethylene sheets could disinfest the soil

on seedbed and produce clean tomato seedlings for transplanting. This could reduce infestations after transplanting the tomato.

## Gaps and challenges

Weed control trials have been carried out only on hot pepper, tomato and onion at very limited sites, and most of the recommendations are manual weeding and herbicide use. Considering the extensive production of vegetables by commercial farmers manual weeding is likely to be impractical. Using herbicides could be an integral part of appropriate methods of weed management. However, appropriate herbicide samples are not easily available to conduct continuous herbicide screening studies in order to come up with more effective and economical herbicides. Moreover, the types of crops and the weeds inflicting damage are many and diverse in the country but the number of professionals dealing with the problem of weeds is still very low. Hence, there is a great demand for more people to be employed/ trained to work on weed management research.

The occurrence of a broomrape fly, *Phytomyza orobanchia*, and a fungus, *Fusarium equiseti* has been reported in Ethiopia. These natural enemies have promising potentials for the control of orobanche. However, no intensive work was done so far. Interdisciplinary team of scientists comprising weed scientists, entomologists and pathologists should work together to come up with an effective bio-control technology to alleviate the orobanche problem in vegetables.

## Prospects

Weed research strategies should give emphasis to further surveys of weed species in major growing areas and screening for new, effective, and economically acceptable herbicides. Since weeds such as *Orobanche ramosa*, *O. cernua* and *O. minor* are becoming very important in vegetable crops like tomato, attention should be given to more research work on these weeds. Studies on the effect of different cultural practices such as crop rotation (use of trap and catch crops), fertilizer, planting periods, tillage practices and irrigation frequency should be intensified. Host plant resistance studies should receive due emphasis. Studies on biological control using the broomrape fly and the fungus *Fusarium equiseti* should be considered seriously. The development of integrated approaches to weed management must be continuously pursued for effective and economical control of weeds in vegetable crops.

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# Status of Weed Research on Fruit Crops in Ethiopia

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## Introduction

Fruit crops are valued for their good source of vitamins, minerals, and proteins. The potential of fruit crops is not well exploited in Ethiopia because of various reasons such as lack of technical knowledge, appropriate production technologies and lack of marketing possibilities. Among fruit crop producers, the Upper Awash Agro-Industry Enterprise (UAAIE) is the largest commercial fruit crops producer and exporter in Ethiopia. Currently, apple, mango, orange, and banana are exported to the Middle East and Europe (Amsalu, 2006). Citrus plantations found in the Oromiya National Regional State contribute bulk of the production in the country. There are four large state plantation farms and one processing plant in the Central Rift Valley of Ethiopia. From the 6903 ha of arable land 1308 ha is allotted to citrus (Abere, 2003). The largest citrus orchard in the country is found at the Nura Era farm with a land holding of 953 ha. Some temperate fruits such as apples, plum and peaches are also produced at a limited scale in the highlands of Ethiopia (Nessel, 2001).

Weeds are among the major constraints in citrus production in general. Weeds harbor disease and insect pests, in addition to their competition for nutrients, soil moisture, light and space. Young growing citrus plants of 1-5 years old are severely affected by the competition from perennial grass and annual broadleaf weeds. The major perennial grass weeds of citrus include *Digitaria abyssinca, Digitaria velutina, Cynadon dactylon, Cyprus rotundus, Cyprus esculetus,* and the broad-leaved weeds *Convolvulus arvensis, Commelina benghalensis, Rumex abyssinica* and *Lactuca intybacea.* (Beyenesh and Etagegnehu, 1992; Giref, 2005).

Limited research on cultural and chemical control of weeds was conducted on citrus (orange, lime, lemon, mandarin and grapefruit) at UAAIE in the past 20 years (Ahmed and Etagegnehu, 1992; Beyenesh and Etagegnehu, 1992). However, no weed researches have been conducted on important tropical and temperate fruit crops such as mango, avocado, papaya, grapevine, guava, ox-heart, casemiro, passion fruit, apples, plums, and peaches.

Dense growth of grass weeds has an adverse effect not only on yield but also on the quality of fruits produced (Seifu, 2003). Therefore, young citrus fruit trees have to be kept weed free. Indirectly, weeds also delay and hinder harvesting of citrus. Hence, effective control of weeds is a prerequisite for quality citrus fruit production. The main objective of this review is to assess gaps in fruit crops weed research and suggest future directions.

# Research findings

## Integrated weed management in pine apple

Effects of integrated weed management on the productivity of pineapple (*Annanas comosus* L.) were studied (Tadesse et al., 2007). The combined effects of different weeding frequencies and other weed control options i. e. hand weeding once, twice weeding, clean weeding, coffee husk mulching supplemented by hand weeding, intercropping of haricot bean as cover crop supplemented with hand and application of Roundup at 3 l/ha supplemented by hand weeding were compared in the experiment. A significant increase in yield and effective control of weeds was attained by integrated application of Roundup supplemented by hand weeding. Combined use of coffee husk mulching and hand weeding, and haricot bean intercropping plus hand weeding was found effective for the control of weeds in pine apple in western Ethiopia (Tadesse et al., 2007).

## Physical weed control

Although physical weed control method was not widely practiced, some leguminous cover crops such as C*rotalaria* sp. are planted between tree rows to improve soil fertility and control weeds in fruit crops at the UAAIE (Mengistu, 2006).

## Cultural control

Vegetative broadleaf or grass weeds are slashed by cutlass or machete in many fruit crops as cultural weed control method in Ethiopia. Slashing of weedy vegetation in fruit crops is performed during the onset of rain beginning from January to end of April and in the main rainfall season from June to end of September every year at the UAAIE. The area under orange and mandarin in UAAIE was 559.7 and 78 hectares, respectively. The person-days requirement for one season slashing weeds in each crop was 835.3 and 1357.5, and the cost was estimated to be 40816.6 and 1226.0 birr/ha, respectively. The overall average man-days/ha required was 14.73 and the cost was 81.6 birr /ha (Mengistu, 2006).

### Chemical control

Non-selective herbicides are used to control perennial grass and broadleaved weeds in citrus plantations. Three newly registered post-emergence herbicides were evaluated on citrus (orange, lemon, mandarins, and grape fruit) and on banana at Merti Juju farms in the Central Rift Valley of Ethiopia (Giref, 2002; 2003; 2004). All of the herbicides tested were effective in controlling perennial grass and annual broad-leaf weeds on citrus and banana, however, the effectiveness appeared to depend on the soil texture and soil organic matter content.

## Conclusion and recommendations

Fruit crops weed research mainly focused only on citrus, banana and pine apple in Ethiopia. However, these results could also be applied to other fruit crops because of their similar growth habits. The recommended herbicides include Roundup (at 3 to 5 l product/ha), Helosate 480 SC (4 l/ha), Mamba 480 SL (4 l/ha), and Touchdown (3 to 3.5 l/ha), while the recommended cultural practices are two slashing (one during the short rainy season between February and April and the second in September).

## Gap and Challenges

A wide range of tropical and temperate fruit crops are grown under irrigated and rain-fed conditions in Ethiopia. However, research on weed control was conducted on a few of them and this is considered as a major gap. Moreover, no exhaustive efforts were made to identify and document the major weed species in the different fruit crops. This needs to be accomplished before integrated management research could be initiated.

## Prospect

The growing importance of fruit crops in Ethiopian agriculture is an opportunity that would stimulate greater attention to be given towards the alleviation of production constraints including weeds.

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# Review of Weed Research in Oil Crops in Ethiopia

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## Introduction

The major oil crops grown in Ethiopia are sesame (*Sesamum indicum*), groundnut (*Arachis hypogeae*), noug or Niger seed (*Guzotia abyssinica*), linseed (*Linum usitatissimum*), rapeseed (*Brassica napus*) and gomenzer or the Ethiopian mustard (*Brassica carinata*). Sunflower, safflower, and castor are also important. Sesame is an herbaceous annual oil crop belonging to the family Pedaliaceae. In Ethiopia, sesame is produced for its seed, which is used for export as whole seed or consumed locally as whole or crushed seed or as cooking oil (Getinet, 1992; Yebio, 1983). The area allotted to sesame in Ethiopia has reached 136,220 ha in 2005 (Table 1), making it the third most important crop among oilseeds (CSA, 2005). In terms of export value, however, it is the first crop among oilseeds accounting for 99.6% of the total volume of oilseeds exported (CSA, 2005). The low-lying regions of Ethiopia adjoining the Sudan are the traditional sesame growing areas. This region stretches from the northwestern tip of the country to southwest and covers Humera-Metemma plain and areas along the Baro River down to Omo valley. In the central parts of the country, sesame is usually found in the low to mid altitude escarpments, which roughly account for half of the sesame production area in the country (Bulcha, 1997; Getinet, 1992).

Groundnut belongs to the family Leguminaceae and is predominantly grown in eastern Hararghe region (the peanut belt of Ethiopia). The low altitude areas (< 1600 masl) in the southwestern and southern parts of the country particularly in Wolega, Ilubabor, Gojam, and Gamo Goffa are also potentially suitable for groundnut production (Bulcha, 1997; Elias, 1988; Getinet *et al*., 1997; Kassahun *et al*., 1991). The total area allotted to groundnut production in Ethiopia is about 20,000 ha (CSA, 2005). The largest proportion of the crop's harvest is locally consumed in the form of snack, margarine, and oil. Besides its use for human consumption, groundnut allows sustainable use of croplands by virtue of its nitrogen fixing ability. Hence, it is a major component in the intercrop or rotation system particularly in Eastern Hararghe (Adugna, 1991).

Table 1. Area, production and yield of sesame and groundnut in Ethiopia (CSA, 2005).

| Year | Sesame | | | Groundnut | | |
|---|---|---|---|---|---|---|
| | Area ('000 ha) | Production (t) | Yield (Kg/ha) | Area ('000 ha) | Production (t) | Yield (Kg/ha) |
| 1998 | 23.6 | 98.3 | 416 | 15.2 | 69.6 | 458 |
| 1999 | 32.2 | 176.8 | 549 | 15.0 | 85.3 | 569 |
| 2000 | 38.2 | 156.3 | 409 | 13.6 | 119.3 | 877 |
| 2001 | 42.4 | 188.8 | 445 | 17.2 | 152.1 | 884 |
| 2002 | 118.3 | 350.7 | 296 | 16.2 | 132.9 | 820 |
| 2003 | 58.8 | 388.9 | 661 | 14.1 | 107.2 | 760 |
| 2004 | 91.5 | 614.6 | 672 | 20.2 | 207.2 | 1026 |
| 2005 | 136.2 | 650.0 | 477 | 20.0 | 210.0 | 1050 |

Noug and linseed grow in almost every region of Ethiopia, linseed with wider distribution than noug. Most of the rapeseed (*Brasica napus*) and gomenzer/Ethiopian mustard (*Brassica carinata)* are produced in Welega, Gojam, Arsi, and Bale (Getinet, 1992). Noug, linseed, rapeseed, and gomenzer are poor competitors with weeds at early stage of growth. Parasitic weeds in noug, linseed, rapeseed, sesame, and groundnut are broadly categorized as annual, perennial, and parasitic weeds (Tadesse *et al*., 1988). Different reports indicated that parasitic weeds like *Orobanche* and *Cuscuta* are serious problems on linseed, noug, and rapeseed. So far, there are no herbicides available to control these weeds in the country (Rezene, 1991).

Weeds compete with crop plants for soil moisture, nutrients, and light; and thereby reduce yield. They also harbor insect pests and disease causing pathogens serving as alternate hosts. The slow initial growth of sesame and groundnut seedlings makes them poor competitors with the more vigorously growing weeds. Sesame has fine and fibrous superficial roots, which are easily damaged during cultivation particularly at the young stage. The very nature of groundnut to develop fruits underground complicates weeding operation. The fibrous root system of weeds also interferes with harvesting of groundnut plants (Kassahun *et al.,* 1988). Hence, preparing a weed free seedbed is crucial to ensure maximum seed yield. Progress on weed research conducted on oil crops prior to 1985 had been reviewed and reported in the past (Tsedeke, 1985). The purpose of this paper is therefore, to review progress made on various aspects of weed research on oil crops in Ethiopia during the last two decades (1985-2005).

# Research findings

## Weeds recorded

About 98 weed species in 30 families were recorded from major oil crops growing areas of the country (Appendix 1). These weeds are either broad leaved, grasses, parasitic weeds or sedges. Broad-leaved species constitute the bulk of these weeds.

## Loss assessment

Crop-weed competition study conducted on sesame for 1984-1986 seasons at Werer Research Center (WRC) revealed that the critical period of competition was during the first 4-5 weeks after crop emergence. Yield loss reaches up to 77% (Tadesse *et al*., 1988). In linseed, weeding at two weeks after crop emergence followed by a mid season weeding before flowering was recommended. The yield reduction caused by weeds in linseed was up to 66% (Table 2).

Table 2. Effect of weeding time on yield of linseed at Holetta from 1980-1982 (after Rezene, 1991).

| Treatments | Yield (t/ha) | Loss (%) |
|---|---|---|
| No weeding | 0.38 | 66.2 |
| Weed free | 1.13 | - |
| Early weeding at 30-35 DAP* | 0.89 | 21.2 |
| Mid season weeding at 50-55 DAP | 0.75 | 33.5 |
| Early + mid season weeding | 0.93 | 17.2 |
| Late weeding at 70-75 DAP | 0.46 | 59.0 |
| Mid + late weeding | 0.77 | 31.3 |

DAP=days after planting

For noug and rapeseed, one hand weeding at the early stage (3-4 weeks after crop emergence) was reported to be adequate to control both broad leaf and grass weeds. Uncontrolled weed growth reduced rapeseed yield by up to 40% (Rezene, 1991). There were no significant differences in yield among weed free, single early weeding and early plus mid season weeding treatments. There was a yield reduction of 47% because of mid season weeding relative to the weed free check. The cost of single early weeding was the lowest followed by early + mid season weeding, and frequent weeding treatments (Table 3). Hence, early weeding was the most profitable treatment for sesame production. Anon (1997) indicate that sesame in the Humera area is weeded late because of labor shortage, and losses due to late weeding range from 30-40%.

Table 3. Cost benefit analysis of weeding on sesame at Werer Research Center (1984 -1986).

| Treatments | Yield (t/ha) | Gross return (Birr/ha) | Cost of weeding (Birr/ha) | Net return (Birr/ha) |
|---|---|---|---|---|
| No weeding | 0.20 | - | - | - |
| Weed free | 1.03 | 632.0 | 249.0 | 383.0 |
| Early weeding at 30-35 DAP | 0.97 | 584.0 | 167.3 | 416.7 |
| Mid season weeding at 50-55 DAP | 0.55 | 248.0 | 322.3 | -74.3 |
| Early + mid season weeding | 1.01 | 616.0 | 243.0 | 373.0 |
| Late weeding at 70-75 DAP | 0.41 | 136.0 | 475.0 | -339.0 |
| Mid season + late weeding | 0.66 | 336.0 | 300.0 | 36.0 |
| CV % | 18.80 | | | |

DAP = days after planting, cost of weeding/person/day = 2.04 Birr sesame price = 0.61 Birr/kg.
Source: Tadesse and Yebio (1988)

At WRC a yield loss of 92% was observed in groundnut in the unweeded check and late weeded plots (Kassahun *et al.*, 1988). While the best yield was obtained when the crop was kept weed free, a single early weeding was found to be economically optimum treatment (Table 4). Results from this trial and other similar studies under rain fed conditions indicated that weeding groundnut not later than four weeks after emergence, supplemented with another hand weeding at the seventh week after crop emergence were economical. Hence, the critical weeding period of groundnut is within 30-35 days after crop emergence, which incidentally is similar to that of sesame.

Table 4. Groundnut yield, labor demand for weeding, cost of weeding and net benefit (1985-87) (after Kassahun and Tadesse, 1988).

| Treatments | Yield (t/ha) | Yield loss (%) | Person (days/ha) | Cost of weeding (Birr/ha) | Net benefit (Birr/ha) |
|---|---|---|---|---|---|
| No weeding | 0.40 | 92.1 | - | - | - |
| Weed free | 5.59 | - | 103.5 | 211.0 | 3409.9 |
| Early weeding at 30-35 DAP | 3.59 | 38.7 | 67.0 | 136.6 | 2075.3 |
| Mid season weeding at 50-55 DAP | 2.92 | 55.8 | 107.7 | 219.7 | 1523.2 |
| Early + mid season weeding | 4.84 | 12.7 | 88.3 | 180.0 | 2906.9 |
| Late weeding at 70-75 DAP | 0.79 | 87.7 | 93.2 | 190.1 | 61.8 |
| Mid season + late weeding | 3.51 | 42.7 | 100.8 | 205.6 | 1948.2 |
| CV % | 33.0 | | | | |

DAP=days after planting, cost of weeding/person/day = 2.04 birr, groundnut price = 0.70 birr/kg.

# Control measures

## Cultural methods

Studies conducted at Asossa and Abobo Research Centers to determine simple or combined effect of weeding stage, ridging and plant spacing revealed that three times hand weeding at Assosa and twice weeding at Abobo had a marked effect on weed control and pod yield of groundnut (Table 5) (IAR, 1985). In eastern Wellega, investigation on the effects of planting date, seed rate, harvesting stage and weeding frequency on sesame yield revealed that weeding sesame at 33 and 55 days after crop emergence resulted in higher seed yield (Tadesse *et al.*, 1988).

Table 5. Effects of ridging and weeding frequency on groundnut yield at Asossa in the 1985/86 season.

| Treatment | Groundnut yield (t/ha) | | | |
|---|---|---|---|---|
| | No weeding | 1-weeding | 2- weedings | 3 weedings |
| Ridging | 0.54 | 1.41 | 1.87 | 1.49 |
| Flat | 0.12 | 1.34 | 1.64 | 2.16 |
| Mean | 0.33 | 1.35 | 1.76 | 1.83 |

Source: IAR, 1985

## Chemical control

Herbicide screening trials conducted on sesame in 1994 and 1995 at WRC indicated that hand weeding at 30-35 DAE followed by metolachlor at 2.5 L $ha^{-1}$ was the most effective against both grass and broad leaf weeds, resulting in a significant increase in sesame seed yield (Table 6) (IAR, 1995; Kassahun, 1994). It was further reported that the herbicide was particularly outstanding against *Portulaca oleraceae*, *Corchorus olitorius* and *Sorghum arundinaceum*. Similarly, the effects of pre- and post-emergence herbicides terbutryn + terbuthylazine, metabromuron, metolachlor, pendimethalin, fluazifop-butyl, betazon and alachlor on weeds of groundnut were investigated at WRC from 1988-1991 (IAR, 1988; 1989). Terbutryn+terbuthylazine and metabromuron at 3.0 kg $ha^{-1}$ and metolachlor at 2.5 kg $ha^{-1}$ gave excellent weed control and the highest yields (Tables 7, 8). Moreover, fluazifop-butyl, terbutryn + terbuthylazine, metabromuron and metolachlor at 2.5 kg $ha^{-1}$ effectively controlled *Portulaca oleraceae, Corchurus olitorius, Sorghum* spp. and *Echnocloa colona* for a prolonged period after application. According to IAR (1995), stomp and lasso were effective on grasses and broad leaf weeds, while fusilade was effective against grass weeds especially on *Sorghum arundinaceum*. Basagran at the highest rate gave very good control of *Cyperus esculentus* and *Cyperus rotundus* at the early stages of the weeds. However, phytotoxicity effect on groundnut was evident at both rates of topogard and

patoran during the early growth stages, though plant recovery was quite satisfactory (IAR, 1995). Several herbicides were also tested to control annual broad leaf and grass weeds in linseed and rapeseed at Holetta and Kulumsa Research Centers. Of the herbicides tested, metabromuron at 2.0, Linuron at 1.0 kg a.i.ha$^{-1}$ in linseed; and alachlor at 1.0 and napropamide at 1.5 kg a.i.ha$^{-1}$ all applied at pre emergence in rapeseed showed greater selectivity, effective control of weeds and high yield (Rezene, 1991).

Table 6. Pre and post-emergence herbicides on seed yield and yield components of sesame at Werer in 1994 and 1995 (after Kassahun, 1997).

| Treatment | Rate (kg/ha) | GWCS (1-9 scale) | | Phyto-toxicity (1-5 scale) | 1000 seed wt (g) | Oil content (%) | Yield (t/ha) |
|---|---|---|---|---|---|---|---|
| | | 20 (DACE) | 45 (DACE) | | | | |
| Chlorbromuron | 3.0 | 3.0 | 3.1 | 0 | 3.8 | 42.1 | 1.66 |
| Antor 48 EC | 2.5 | 3.2 | 3.8 | 0 | 3.8 | 42.2 | 1.62 |
| Fluzifop-butyl | 2.0 | 6.1 | 3.2 | 0 | 3.7 | 42.0 | 1.68 |
| Metolachlor | 2.5 | 1.0 | 1.8 | 0 | 3.8 | 41.7 | 1.86 |
| Hand weeding 30-35 DACE | - | 1.0 | 0.9 | - | 3.8 | 43.0 | 2.04 |
| Unweeded | - | 9.0 | 9.0 | - | 3.8 | 41.7 | 0.25 |
| Mean | | | | | 3.75 | 42.1 | 1.64 |
| CV% | | | | | 3.27 | 0.69 | 12.75 |

GWCS= general weed control score 1=complete control and 9 = no control, DACE =days after crop emergence, phytotoxicity score 0 = no damage and 5 = extremely damaged

Table 7. Phytotoxicity score and pod yield of groundnut as affected by herbicides under irrigated conditions during 1994 and 1995 ( IAR, 1994 and 1995).

| Treatments | Rate (kg/ha) | Phytotoxicity score (0-5 scale) | | Yield (t/ha) |
|---|---|---|---|---|
| | | 20 (DACE) | 45 (DACE) | |
| Terbutryn+terbuthylazine | 3.0 | 2.0 | 0 | 5.65 |
| Metabromuron 50WP | 3.0 | 2.75 | 0 | 5.78 |
| Metolachlor 960 EC | 2.5 | 0 | 0 | 5.45 |
| Pendimethalin | 2.0 | 0 | 0 | 3.54 |
| Fluazifop-butyl | 1.0 | 0 | 0 | 3.95 |
| Betazon | 2.5 | 0 | 0 | 4.60 |
| Alachlor | 4.0 | 0 | 0 | 3.95 |
| Hand weeding x 2 (30 and 55 DACE) | | | | 6.63 |
| Unweeded | | | | 8.05 |
| Mean | | | | 4.38 |
| CV (%) | | | | 14.3 |

DACE = days after crop emergence, phytotoxicity score of 0= no damage and 5= extremely damaged.

Table 8. Herbicide verification trial on irrigated groundnut at Werer in 1995 (after Kassahun, 1997).

| Herbicide | Rate (kg/ha) | Yield (t/ha) |
|---|---|---|
| Terbutryn+ terbuthylazine | 1.5 | 4.01 |
| Metabromuron | 4.0 | 3.60 |
| Metolachlor 960 EC | 2.5 | 4.60 |
| Hand weeding x 2 (30 and 55 DCAE) | - | 5.10 |
| Unweeded | - | 2.70 |
| CV % | | 9.6 |

DACE = days after crop emergence.

## Integrated weed management

Effects of different weed management options involving hand weeding, hoeing and herbicide application on groundnut were investigated for two years under irrigated conditions at Werer. Fluazifop-butyl supplemented with hoeing gave significantly reduced weed fresh weight, particularly due to its excellent effect on the dominant grass weeds. Codal at 5.0 kg $ha^{-1}$ and Metholachlor at 2.5 kg $ha^{-1}$ with supplementary hoeing also gave better control of the major broadleaved and grass weeds. Twice hand weeding had also the lowest weed fresh weight. The combination of herbicide and hoeing treatments gave higher pod yield than the herbicide treatment alone (Table 9) (IAR, 1998).

Table 9. Effect of different weed management systems on weed biomass and groundnut yield at Werer during 1997 and 1998 (IAR, 1998).

| Treatments | Rate (Kg/ha) | Pod yield (t/ha) |
|---|---|---|
| Unweeded | - | 0.65 |
| Select 2Bc | 0.4 | 1.54 |
| Metolachlor | 2.5 | 3.93 |
| Codal | 5.0 | 3.99 |
| Propaquizafop | 1.5 | 2.15 |
| Fluzifop-butyl | 2.5 | 2.97 |
| Trifluralin | 2.5 | 2.53 |
| Metolachlor + Hoeing (30 DAE) | 2.5 | 4.92 |
| Codal + Hoeing (30 DAE) | 5.0 | 6.29 |
| Propaquizafop + Hoeing (45 DAE) | 1.5 | 5.12 |
| Fluzifop-butyl + Hoeing (45 DAE) | 2.5 | 5.57 |
| Trifluralin + Hoeing (30 DAE) | 2.5 | 4.95 |
| Select + Hoeing (45 DAE) | 0.4 | 4.52 |
| Hand weeding (30 and 35 DAE) | | 5.78 |
| Mean | | 3.34 |
| CV % | | 10.45 |

## Tillage

Studies conducted on the effects of plowing frequency and herbicides on the most dominant and noxious grass weeds (*Cyperus rotundus* and *C. esculentus*) in sesame and groundnut at Werer showed that there was no marked effects of treatments on the weed population (IAR, 2002). However, twice plowing at the depth of 40 cm at 25 days intervals gave the highest yield, while the conventional tillage gave the lowest (Table 10).

Table 10. Effects of plowing frequency and herbicides on *C. rotundus* and *C. esculentus* and pod yield of groundnut at Werer during 2000-2002.

| Treatments | DWB (g) | Percent control | | | Pod yield (t/ha) |
|---|---|---|---|---|---|
| | | 15 DACE | 35 DACE | 56 DACE | |
| F0H0 | 2.3 | 23.1 | 42.4 | 85.8 | 3.00 |
| F0H1 | 2.3 | 29.2 | 51.4 | 80.2 | 3.41 |
| F0H2 | 1.7 | 29.7 | 60.4 | 86.4 | 2.90 |
| F0H3 | 0.8 | 38.2 | 71.0 | 93.6 | 2.53 |
| F1H0 | 2.8 | 24.4 | 52.6 | 81.8 | 4.13 |
| F1H1 | 2.4 | 26.6 | 47.6 | 85.1 | 3.81 |
| F1H2 | 0.9 | 36.7 | 69.9 | 99.6 | 3.70 |
| F1H3 | 2.0 | 34.4 | 68.7 | 98.8 | 3.10 |
| F2H0 | 2.4 | 24.3 | 47.2 | 78.1 | 4.44 |
| F2H1 | 1.7 | 23.3 | 46.6 | 93.6 | 3.83 |
| F2H2 | 1.0 | 23.8 | 61.3 | 91.2 | 3.37 |
| F2H3 | 0.7 | 32.4 | 65.6 | 97.4 | 3.11 |
| F3H0 | 1.1 | 33.1 | 57.4 | 85.6 | 4.07 |
| F3H1 | 1.8 | 31.7 | 55.8 | 88.6 | 4.11 |
| F3H2 | 0.9 | 43.2 | 62.8 | 87.2 | 3.73 |
| F3H3 | 1.2 | 44.3 | 67.0 | 75.4 | 3.17 |
| Mean | 1.6 | 31.1 | 57.5 | 88.0 | 3.52 |
| CV | 14.31 | | | | |

DWB = dry weed biomass, DACE = days after crop emergence, FO = conventional, F1= 1Tillage, F2= 2 tillages, F3=3 tillages, H0= no herbicide, H1= 25 g/ha, H2= 50g /ha and H3= 75 g/ha ( IAR, 2002).

# Conclusion and recommendations

Uncontrolled weed growth resulted in yield reduction of up to 77% in sesame and up to 90% in groundnut. Weeding sesame once at about four weeks and groundnut twice at about four and seven weeks after crop emergence were found to be economical in the production of both crops. Plowing frequency, herbicide application, or a combination of these did not affect *Cyperus* species. Nonetheless, twice plowing to a depth of 40 cm at 25 days interval increased groundnut yield, indicating the advantage of plowing regardless of its effect on

weed control. In groundnut, Terbutryn+terbuthylazine at the rate of 1.5 L $ha^{-1}$, Metabromuron at 4.0 kg $ha^{-1}$ and Metolachlor at 2.5 L $ha^{-1}$ gave broad-spectrum weed control and thereby resulted in a significant increase in groundnut seed yield. Fluzifop-butyl suppressed grass weeds especially *Sorghum arundnacea.* Betazon at the highest rate effectively controlled both *Cyperus esculentus* and *C. rotundus* at the early growth stages of the weeds. However, Terbutryn+terbuthylazine and Metabromuron during the early growth stages were found to be phytotoxic to the groundnut plants.

In sesame, Metolachlor at the rate of 2.5 L $ha^{-1}$ was most effective against both grass and broad leaf weeds and produced comparable sesame yield to two times hand weeding. Metolachlor was particularly effective against *Portulaca oleraceae, Corchorus olitorius Gaynandropis gaynandra, Borehaavia erecta, Setaria* spp.*, Echinocloa* spp. and *Sorghum arundinaceaum.* However, phytotoxicity effects on sesame were observed during the early growth stage, though plant recovery was quite satisfactory. As for groundnut, herbicide application needs to be supplemented with cultivation and/or slashing as necessary.

For linseed, weeding at two weeks after crop emergence followed by a mid season weeding before flowering are recommended. In noug and rapeseed, on the other hand, one hand weeding at early stage (three to four weeks after crop emergence) is adequate to control both broad leaf and grass weeds. Metabromuron at 2.0, Linuron at 1.0 kg a.i.$ha^{-1}$ in linseed and Alachlor 1.0 and Napropamide at 1.5 kg a.i.$ha^{-1}$ at pre emergence in rapeseed showed greater selectivity, effective control of weeds and good yield. In groundnut, Fluazifop-butyl + hoeing were effective in controlling particularly grass weeds, while Codal + hoeing increased seed yield. In general, integrating different weed management options that include hand weeding, hoeing and herbicide application is important to contain the build up of problematic weeds.

## Gaps and challenges

- Lack of full time researchers in the field of weed science
- Weed surveys, loss assessment, critical weeding period and weed control studies are still lacking for many major oil crops in major growing areas in the country
- Studies on integrated weed management (IWM) practices are inadequate or lacking in many production zones of these crops
- Control measures for noxious weeds like *Cyperus, Prosopis, Parthenium* and parasitic weeds such as *Orobanche* and *Cuscuta* are

lacking. The available cultural methods of weed control are not yet widely verified

- Little attention was given to system analysis studies on appraisal of weed problems and farmers indigenous knowledge on weed management
- The threat of alien invasive weed species and lack of awareness at points of introduction
- High incidence of weed shift resulting from weed carryover from the highlands to farms located in the Awash Valley due to flooding of the Awash River.

## Prospects

The loss incurred due to weeds in oil crops is enormous. A well-coordinated research effort to curb the problem of weeds in oil crops production is critically important. Thus, the following areas of research are suggested:

- Quantitative and qualitative surveys and studies on loss assessment and critical weeding periods should be conducted before embarking on control measures
- The available weed control practices should be widely verified in different production areas with different weed infestation levels and weed species distribution
- Integrated weed management studies should be conducted on economically important weeds both in irrigated and rain fed oil crop growing areas of the country
- Targeted research on specific weeds like Parthenium hysterophorus, Prosopis juliflora, Cyperus, Orobanche and Cuscuta spp. should be undertaken
- Research on the management of weeds in oil crops in Ethiopia should follow the IPM approach concentrating on cultural practices, host plant resistance, chemical and biological control methods that are feasible and affordable
- Explorations of indigenous weed management practices and knowledge should be pursued aggressively
- Studies on the evaluation of competitive abilities of oil crop cultivars against weeds should be encouraged as an additional component of integrated weed management system
- The efforts of breeders and physiologists in developing and evaluating agronomically competitive cultivars should be increased

Appendix 1. Weed species recorded in major oil crops in Ethiopia.

| Weed species | Abundance in different crops | | | | | References |
|---|---|---|---|---|---|---|
| | Noug | Linseed | Rapeseed | Sesame | Groundnut | |
| **Aizoaceae** | | | | | | |
| *Zalya pentandra* | - | - | - | xxx | xxx | 2,33,38 |
| **Amaranthaceae** | | | | | | |
| *Achyranthes aspera L.* | *x* | x | x | x | x | 33,35,38 |
| *Amaranthus hybridus* | *x* | x | x | x | x | 33,35,38 |
| **Asteraceae** | | | | | | |
| *Bidens pilosa* L. | *xxx* | xxx | xxx | x | xx | 33,35,38 |
| *Blumea aurita* (L.f) DC. | - | - | - | x | x | 35,38 |
| *Flaveria trinervia* | - | - | - | xx | xxx | 33,35,38 |
| *Galinsoga parviflora* Cav. | *xx* | xx | xxx | x | xx | 33,35,38 |
| *Gnaphelium unionis* D.Don. | *x* | x | x | x | x | 33,35,36,38 |
| *Guizotia scabra* | *xx* | xx | xx | x | x | 33,35,38 |
| *Launea cornuta* | *xx* | xx | x | x | xx | 33,35,38 |
| *Parthenium hysterophorus L* | *xx* | xx | xx | xxx | xxx | 25,38 |
| *Sonchus arvensis* | *x* | xx | xx | x | x | 33,35,38,40 |
| *Tagetes minuta* | *xx* | xx | xx | x | xx | 35,38 |
| *Xanthium spinosum* | *x* | x | x | xx | xxx | 2,33,35,38 |
| *Xanthium strumarium* | *x* | x | x | xx | xx | 2,33,35,38 |
| **Brassicaceae** | | | | | | |
| *Raphanus raphanistrum* | *xx* | xxx | xx | x | xx | 33,35,38 |
| *Sinapis arvensis* | *x* | x | x | x | x | 33,38 |
| **Capparidaceae** | | | | | | |
| *Gynandropis gynandra* | - | - | x | xx | xxx | 33,35,38 |
| **Chenopodiaceae** | | | | | | |
| *Chenopodium album* L. | *x* | x | x | x | x | 37,35,38 |
| *Chenopodium ambrosiodes* L. | *x* | x | x | x | x | 35,38 |
| **Commelinaceae** | | | | | | |
| *Commelina Africana* | *xx* | x | x | x | xx | 35,36,38 |
| *Commelina benghalensis* L. | *xx* | xxx | xx | x | xx | 36,38 |
| **Caryophyllaceae** | | | | | | |
| *Corrigiola capensis* | *xx* | x | x | x | x | 36,38 |
| *Spergula arvensis* L. | *xx* | xx | xx | x | xx | 36,38 |
| **Convolvulaceae** | | | | | | |
| *Convolvulus arvensis* | *x* | x | x | x | x | 33,35,36,38 |
| *Cuscuta campestris* | *xxx* | x | x | x | x | 36,38 |
| *Cuscuta hyalina* | *x* | x | x | x | x | 36,38 |
| *Ipomoea aquatica* | - | - | - | xx | xx | 33,36,38 |

Appendix 1. Contd.

| Weed species | Abundance in different crops | | | | | References |
|---|---|---|---|---|---|---|
| | **Noug** | **Linseed** | **Rapeseed** | **Sesame** | **Groundnut** | |
| **Cucurbitaceae** | | | | | | |
| *Cucumis dipsaceus* | - | - | - | x | x | 33,36 |
| *Cucumis melo* | - | - | - | x | x | 2,33,36 |
| **Cyperaceae** | | | | | | |
| *Cyperus rotundus L.* | *xx* | xx | xx | xx | xxx | 33,35,36,38 |
| *Cyperus bulbosus* | - | - | - | xx | xx | 33,36 |
| *Cyperus esculentus* L. | *x* | x | x | xx | xxx | 33,35,36,38 |
| **Euphorbiaceae** | | | | | | |
| *Acalypha crenata* | - | - | - | x | x | 33,35 |
| *Chrozophora plicata* | - | - | - | x | x | 23,33 |
| *Euphorbia heterophylla* | *x* | x | x | x | x | 23,33,36 |
| *Euphorbia indica* Lam. | *x* | x | x | x | x | 33,35 |
| *Tragia plukenetil* | - | - | - | x | x | 33 |
| **Fabacea** | | | | | | |
| *Alysicarpus glumaceus* | - | - | - | x | x | 23,36 |
| *Indigofera schimperi* | - | - | - | x | x | 23 |
| *Medicago polymorpha* | *xxx* | xxx | xxx | x | x | 33,36,38 |
| *Prosopis juliflora* | - | - | - | xx | xx | 28,38 |
| *Pseudarthria hookeri* | - | - | - | x | x | 23 |
| *Scorpiurus muricatus* | *xx* | xx | xx | x | x | 33,36,38 |
| *Trifolium* sp. | *xx* | xx | x | x | x | 33,38 |
| **Juncaceae** | | | | | | |
| *Jancus* spp | *x* | x | x | x | x | 36,38 |
| **Lamiaceae** | | | | | | |
| *Ocimum canum* | - | - | - | x | x | 23,36 |
| **Nyctaginaceae** | | | | | | |
| *Boerhavia coccinea* | *x* | x | x | xx | xxx | 23,36 |
| *Borehavia erecta L.* | - | - | - | xxx | xxx | 23,33,36 |
| *Borehavia repens* | *x* | x | x | xx | x | 23,33,36 |
| **Orobanchaceae** | | | | | | |
| *Orobanche ramosa* | *x* | - | - | - | *x* | 2,6,38 |
| *Orobance minor* | *x* | - | - | - | *x* | 2,6,38 |
| **Oxalidaceae** | | | | | | |
| *Oxalis corniculata* L. | *x* | x | xx | x | x | 33,36,38 |
| **Papaveraceae** | | | | | | |
| *Argemone mexicana* | *x* | x | x | x | x | 33,38 |
| **Plantaginaceae** | | | | | | |
| *Plantago lanceolata* L. | *xxx* | xx | xxx | x | x | 36,38 |
| *Plantago major L.* | *xxx* | xx | xx | x | x | 36,38 |

Appendix 1. Contd.

| Weed species | Abundance in different crops | | | | | References |
|---|---|---|---|---|---|---|
| | Noug | Linseed | Rapeseed | Sesame | Groundnut | |
| **Poaceae** | | | | | | |
| *Andropogon abyssinicus* | *x* | x | x | x | x | 33,38 |
| *Avena fatua* L. | *xx* | xx | x | x | x | 33,38 |
| *Bromus pectinatus* | *x* | x | x | x | x | 33,38 |
| *Cenchrus ciliaris* L. | *x* | x | x | x | x | 33,36,38 |
| *Cynodon dactylon* (L.) | *x* | x | x | xx | xx | 33,38 |
| *Digitaria scalarum* L. | *x* | x | x | xx | xx | 36,38 |
| *Dinebra retroflexa* | - | - | - | x | x | 23,33 |
| *Diplachne caudata* | *x* | x | x | x | x | 23,33 |
| *Echinocloa colona L.* | *xx* | xx | xx | xx | xx | 33,35,36,38 |
| *Echinocloa crusgalli* . | *xx* | xx | xx | xx | xx | 33,35,36,28 |
| *Eleusine indica* (L.) . | *x* | x | x | xx | xx | 33,35,36,38 |
| *Eragrostis aethopica* | *x* | x | x | x | x | 33,36,38 |
| *Eragrostis ciliaris* | - | - | - | x | x | 33,36 |
| *Eriochloa fatmensis* | *x* | x | x | x | x | 33,36,38 |
| *Hemarthria natans* stapf | - | - | - | x | x | 23 |
| *Lolium temulentum* | *x* | x | x | x | xx | 23,33,38 |
| *Panicum repens* | *x* | x | x | x | xx | 23,33,36 |
| *Pennisetum* spp. | *x* | x | x | x | x | 23,33,38 |
| *Phalaris paradoxa* | *xxx* | xxx | xxx | xx | xx | 36,38 |
| *Poa annua* L. | *x* | x | x | xx | xx | 33,38 |
| *Setaria pumila* (L.) | *xxx* | xxx | xxx | x | xx | 33,35,38 |
| *Setaria verticillata* (L.) | *xxx* | xxx | xxx | x | x | 33,35,38 |
| *Snowdenia polystachya* . | *xxx* | xxx | xxx | x | xx | 33,35,38 |
| *Sorghum arundinaceum* | *x* | x | x | xxx | xxx | 33,38 |
| *Tragus rcemosus* | - | - | - | x | x | 33,36 |
| **Polygonaceae** | | | | | | |
| *Oxygonum sinuatum* | *xxx* | xxx | xxx | x | x | 33,35,36,38 |
| *Polygonum aviculare* L. | *xx* | xx | xx | x | x | 33,38 |
| *Polygonum convolvulus* L. | *x* | x | x | x | x | 33,38 |
| *Polygonum nepalense* L. | *xx* | xx | xx | x | x | 33,38 |
| *Rumex abyssinicus* L. | *xx* | xx | xx | x | x | 33,38 |
| **Portulaceae** | | | | | | |
| *Portulaca oleracea L.* | - | - | - | xxx | xxx | 23,33 |
| **Primulaceae** | | | | | | |
| *Anagallis arvensis* L. | *xx* | xx | xx | x | x | 33,38 |
| **Resedaceae** | | | | | | |
| *Caylusea abyssinica* | *xxx* | xx | xxx | x | x | 38 |
| **Rubiaceae** | | | | | | |
| *Galium aparine* L. | *xx* | x | xx | x | x | 33,38 |
| *Galium spurium* L. | *xx* | xx | x | x | x | 33,38 |

Appendix 1. Contd.

| Weed species | Abundance in different crops | | | | | References |
|---|---|---|---|---|---|---|
| | Noug | Linseed | Rapeseed | Sesame | Groundnut | |
| **Solanaceae** | | | | | | |
| *Datura stramonium* | *xx* | xxx | xx | x | x | 36,38 |
| *Nicandra physaloides* | *x* | x | x | xx | xxx | 33,35,38 |
| *Solanum dubium* | - | - | - | x | x | 33,36 |
| *Solanum incanum* | *x* | x | x | x | x | 33,36,38 |
| *Solanum nigrum* | *x* | x | x | x | x | 33,36 |
| **Tiliaceae** | | | | | | |
| *Corchorus olitorius* | - | - | - | xxx | xx | 33,36 |
| **Zygophyllaceae** | | | | | | |
| *Tribulus terrestris* | *x* | x | x | x | x | 33,38 |

Note: xxx = major weed, xx= important weed x=commonly occurring weed, - = not reported.

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# Review of Coffee Weed Research in Ethiopia

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## Introduction

Coffee is the single most important commercial crop in Ethiopia contributing 35-40% of foreign exchange earnings. In Ethiopia, coffee grows at various altitudes ranging from 550- 2750 masl, and under 4 production systems: forest, semi-forest, garden, and plantation coffee accounting for 10, 34, 35 and 21%, respectively, of the total volume produced, (Workafes, 1999). The coffee growing areas are characterized by high rainfall and suitable temperature and edaphic conditions which also encourage the growth of diverse weed flora ranging from abundant seed producing annuals to hard-to-control rhizomatous and stoloniferous perennial grasses and sedges. Research experience has shown that weeds can be serious competitors. Perennial grasses, sedges, and annual weeds with their fast and vigorous growth characteristics can easily smother the coffee plant and may result in extremely low yields and poor quality coffee.

The warm, wet, and humid conditions prevailing in the coffee growing areas not only result in diverse weed flora but also encourage the continuous growth of weeds necessitating weed control throughout the growing period. As a result, weed control is one of the major operations, which entails high cost (Bayessa *et al*, 1988). The majority of coffee producers (90%) are subsistence farmers who cannot afford the purchase of chemical herbicides. Therefore, they heavily depend on manual slashing and digging for the management of perennial weeds. These traditional practices of slashing and digging encourage the multiplication and spread of the perennial weeds in coffee (Mesfin, 1990). However, the use of herbicides for weed control in coffee is growing steadily in the state farms. Good weed management and effective weed control require as much better understanding of weed response to changes in cultural methods and the application of herbicides. Hence, Integrated Weed Management (IWM) is the most promising alternative strategy, because it emphasizes the proper utilization of cultural, mechanical, and chemical methods for sustainable coffee production. This paper attempts to review weed research activities in coffee since 1985.

# Research findings

## Weed survey

Coffee is predominantly produced in the south and southwest parts of the country where the weed population is diverse (Table 1). Systematic surveys on weeds of coffee in Ethiopia have not been conducted. However, based on visual scoring and subjective types of ranking, different researchers have attempted to identify and categorize the major weed species in coffee (Getachew, 1991; Lakew, 1987, Paulos, 1985, Tadesse, 1992).

Getachew (1991) recorded 63 species of weeds in 23 families in coffee. Since weeds undergo continuous emergence exposing only a small part of them, an actual flora represents only a limited percentage of the potential flora i.e. only part of the seed bank in the soil. The numbers and type of weed seeds in the soil may not correlate with the number and population of emerged weeds. Hence, species listed here as coffee weeds represent only a small portion of the potential weeds of the crop.

Most of the economically important coffee weeds are shade sensitive grassy and sedge species that are difficult to control manually because of the underground-interconnected rhizomes, which serve as storage and reproductive structures for rapid multiplication (Paulos, 1985). The fact that these weeds do not tolerate low light intensities is, however, an important feature that needs to be considered in weed management strategy.

Table 1. Coffee weeds recorded in Ethiopia.

| Scientific name | English name | Status | References |
|---|---|---|---|
| **Cypraceae** | | | |
| *Cyperus esculentus* L. | Yellow nut sedge | Common | 2, 10 |
| *C. rotundus* L. | Purple nut sedge | Common | 2, 8, 11 |
| *Kyllinga cylendrica* Nec | Creeping sedge | Common | 2 |
| *K. elatoir Kunt* | Creeping sedge | Rare | 2 |
| *Marascus hemisphaericus* | Sedge | Rare | 2 |
| *Marascus* sp. | Sedge | Rare | 2 |
| *Marascus umbillatus* | Sedge | Rare | 2 |
| **Poaceae (Gramineae)** | | | |
| *Cynodon dactylon* (L.) Pers | Star grass | Common | 2, 8, 10 |
| *C. nlemfuensis* (Venderyst) | Star grass | Common | 2,10,11 |
| *Digitaria abyssinica* (A. Rich) stapf | Blue coach grass | Common | 2, 8, 10, 11 |
| *Oplisminus hirtellus* (L.) P. Beauv | Blue coach grass | Rare | 2 |
| *Panicum maximum* Jack | Guinea grass | Rare | 2 |
| *Paspalum conjugatum* berg | Buffalo grass | Common | 2 |
| *P. commonsoni lam* | Buffalo grass | Rare | 2 |
| *Setaria chevalieri* | Buffalo grass | Rare | 2 |
| *Sorghum verticillifrum* | Sudan grass | Rare | 2 |
| *Sporobulus pyramidalis* (Beauv.) | Sudan grass | Rare | 2 |
| **Amaranthaceae** | | | |
| *Amaranthus dubius* Mart | Pig weed | Common | 2 |
| *A. lividus* L. | Pig weed | Common | 2 |
| **Asteraceae** | | | |
| *Ageratum conyzoides* (L.) | Goat weed | Common | 2, 8, 10, 11 |
| *Bidens pilosa* L. | Black Jack | Common | 2, 8, 10, 11 |
| *Conyza bonariensis* (L.) Cronquist | Flea bane | Rare | 2 |
| *Dichlorocephlla inteqrifalia* (L.) Ktfe | Flea bane | Rare | 2 |
| *Galinsoga cilliata* (Rufn.) Black | Shaggy galent | Rare | 2 |
| *G. parviflora* | Gallent soldier | Common | 2, 8, 10, 11 |
| *Sonchus asper* (L.) Hiv | Gallent soldier | Rare | 2 |
| **Boraginaceae** | | | |
| *Cynoglossum lancifolium* Bak. & Wright | Forget-me-not | Rare | 2 |
| **Caryophylaceae** | | | |
| *Setellaria senni* Chiov | Forget-me-not | Rare | 2 |
| **Convolvulaceae** | | | |
| *Cuscuta campestris* | Dodder | Common | 2, 8, 10, 11 |
| **Crucifereae (brasscaceae)** | | | |
| *Cardamine trichocarpa* (Hochst ex A. Rich) | Dodder | Rare | 2 |
| **Cucurbita** | | | |
| *Coccinia* sp. | Dodder | Rare | 2 |
| **Euphrobiaeae** | | | |
| *Acalypha brachystaceae* Hernun | Dodder | Rare | 2 |
| *Euphrobia hirta* L. | Dodder | Rare | 2 |
| *Phylanthus leucanthus* | Dodder | Rare | 2 |

Table 1 contd.

| **Scientific name** | English name | Status | Ref. |
|---|---|---|---|
| **Labiateae** | | | |
| *Leucas martinicensis* (Jacq) Ait. F | Athma weed | Rare | 2 |
| **Oxalidaceae** | | | |
| *Oxalis corniculata* L. | | | 2 |
| **Polygonaceae** | | | |
| *Polygonium nepalense* Meissn | Knot grass | Rare | 2,10,11 |
| **Portulacaceae** | | | |
| *Portulaca oleraceae* L. | Pursulane | Common | 2 |
| **Rubiacea** | | | |
| *Galium spurium* L. | Goose grass | | 2 |
| *Odenlandis corymbossa* L. | Goose grass | | 2 |
| **Fabaceae (papilionaceae)** | | | |
| *Indigofera spicata* Fosk | Creeping weed | Common | 2 |
| *Desmodium adscendens* | Creeping weed | Common | 2 |
| **Malvaceae** | | | |
| *Sida collina* | Sida | Common | 2 |
| **Poligonaceae** | | | |
| *Rumex bequartii* De Wild | Dock | Common | 2 |
| **Urticaceae** | | | |
| *Fleuriya* sp. | Dock | Rare | 2 |
| **Vitaceae** | | | |
| *Stphostema adenocale* (L.) Urb | Wild vine grape | Rare | 2 |

## Crop loss in coffee

A crop loss assessment study at Jimma Research Center (JRC) in established coffee fields showed a yield loss of 65% when weeding was totally abandoned (Table 2). In an other study, total N content of coffee seedlings was reduced by 49% when couch grass was allowed to compete full season (Table 3). These results indicate that weeds can seriously compete with coffee bushes and weeding is a vital operation in coffee production.

Table 2. Coffee yield as affected by different weeding methods (after Tadesse, 1998).

| **Weed control method** | **Yield (Q/ha$^{-1}$ clean coffee)** | | | | **Yield loss** |
|---|---|---|---|---|---|
| | **1993** | **1994** | **1995** | **Mean** | **(%)** |
| No weeding | 2.00 | 1.67 | 4.40 | 2.69 | 65 |
| 3 x slashing | 3.54 | 2.43 | 7.98 | 4.65 | 40 |
| 5 x slashing | 3.75 | 3.15 | 9.50 | 5.46 | 30 |
| 10 x slashing | 4.47 | 4.20 | 11.28 | 6.65 | 14 |
| 1 Slashing + 1 glyphosate* | 4.04 | 2.96 | 9.94 | 5.65 | 27 |
| Clean weeding | 5.38 | 5.10 | 12.74 | 7.74 | - |
| LSD (5%) | 1.03 | 1.04 | 2.00 | - | - |
| LSD (1%) | 1.45 | 1.44 | 2.87 | - | - |

*Glyphosate at 4 liters of product ha$^{-1}$

Table 3. Effect of clipping frequency of couch grass on growth and leaf nitrogen content of coffee seedlings (after Tadesse, 1992).

| Clipping interval (weeks) | Clipping frequency (n) | Couch grass dry weight (g) | Coffee dry weight (%) | Loss in total dry weight (%) | Total N | Loss (%) |
|---|---|---|---|---|---|---|
| 1 | 32 | 280[a] | 177[b] | 43 | 2.00 | 31 |
| 2 | 16 | 287[a] | 168[b] | 44 | 1.98 | 33 |
| 4 | 8 | 678[b] | 118[c] | 72 | 1.76 | 39 |
| 6 | 6 | 908[c] | 88[d] | 72 | 1.48 | 49 |
| 8 | 4 | 930[c] | 83[d] | 70 | 1.33 | 54 |
| 10 | 3 | 925[c] | 82[d] | 70 | 1.32 | 54 |
| Weed free | - | - | 307[a] | - | 2.88 | - |
| Unclipped | - | 927[b] | 85[d] | 71 | 1,47 | 49 |

Means followed by the same letter within a column are not significantly different from each other at 5% level (DMRT).

# Weed control methods

## Slashing and Digging

Slashing and digging are the major methods of weed control employed by the majority of coffee growers (Kassahun, 1994; Bayessa *et al*, 1988). Weed slashing is a fast operation useful for the control of annual broad-leaved weeds, but with little effect on the control of perennial grasses and sedges. According to Kassahun (1994), the majority of coffee farmers use 2 slashings in one crop season to control weeds, which is hardly adequate to suppress weed growth and increase yield.

According to Mesfin (1990), slashing assists the multiplication of perennial weeds, since farmers cannot totally uproot the rhizomes which grow into the soil as deep as one meter or more. Research conducted at JARC has shown that slashing of perennial weeds beyond 4 weeks interval had no or little effect on yield suggesting that the slashing interval is critical and should be performed with closer intervals in order to exhaust the underground reserves (Tadesse, 1998). On the other hand, in a yield loss assessment study, it was found that coffee which received 10 slashings per season suffered 14% yield loss indicating that even if weeds are slashed more frequently, there is always considerable amount of yield loss to be incurred (Table 2).

Generally, sole dependence on slashing and digging alone for weed control in coffee is insufficient, costly and also detrimental to the coffee trees. Slashing using the bushman knife usually wounds the coffee tree predisposing it to a

fugal disease called *Gibberella xylariodes,* which ultimately kills the tree. Similarly, control by digging is not practical in established coffee since the attempt to dig out the rhizomes and tuber chains is highly injurious to the coffee feeder roots. Moreover, digging fragments and disperses the rhizomes in the field. Hence, thorough cultivation is recommended only during land preparation. However, digging is a common practice in the southern and eastern coffee growing areas. This practice is laborious, time consuming with little effect on the control of perennial weeds. Nevertheless, slashing and digging with proper timing could be vitally useful in the integrated weed management (IWM) program.

## Cover cropping

Studies at JRC showed that crops such as noug, soybean, chickpea, lentil, and linseed are good cover crops for the control of couch grass, the most detrimental weed of coffee (Tables 4, 5, 6 and 7). Noug (*Guzotia abyssincia* L.) at the rate of 20 kg ha$^{-}$ effectively suppressed couch grass in coffee more than did chickpea, lentil, linseed, and soybean (Tables 4, 5, 6 and 7). As a result, coffee yield significantly increased under the cover crops as compared to the common practice of slashing (Table 8). Nevertheless, along with the selection of suitable cover crops, the level of fertilizer required for the coffee tree growing with the cover crop, the seed rate and the proper time of planting of the cover crop need further investigation. It is indispensable to use cover crops as part of IWM program for sustainable coffee production.

Table 4. Effect of cover crops on percentage cover of couch grass in 1981 after three seasons of spring and fall crops planting of cover crops ( after Paulos, 1987).

| **Treatment (spring crop)** | **End of spring Fall crops** | | | | | **End of fall Fall crops** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Slashing** | **Chickpea** | **Lentil** | **Linseed** | **Mean** | **Slashing** | **Chickpea** | **Lentil** | **Linseed** | **Mean** |
| Slashing | 95 | 86 | 89 | 94 | 91 | 96 | 52 | 66 | 39 | 63 |
| Noug | 20 | 6 | 5 | 4 | 9 | 45 | 34 | 32 | 12 | 31 |
| Bean | 26 | 17 | 9 | 10 | 15 | 53 | 22 | 36 | 15 | 31 |
| Soybean | 31 | 11 | 10 | 10 | 16 | 26 | 29 | 32 | 20 | 27 |
| Mean | 43 | 30 | 28 | 29 | 33 | 55 | 34 | 41 | 21 | 38 |
| LSD 5% and 1% between spring crops means | | | | | | 6.77 and 9.72 | | | | 18.34 and 26.36 |
| LSD 5% and 1% between spring crops means | | | | | | 6.53 and 7.16 | | | | 12.09 and 16.22 |

Table 5. Effect of cover crops on percentage cover of couch grass in coffee farm at the end of the fall crop in 1982 (after Paulos, 1987).

| Treatments (spring crop) | Treatment (fall crops) | | | | |
|---|---|---|---|---|---|
| | **Slashing** | **Chickpea** | **Lentil** | **Linseed** | **Mean** |
| Slashing | 85 | 77 | 55 | 59 | 69 |
| Noug | 62 | 34 | 32 | 14 | 35 |
| Bean | 79 | 60 | 22 | 42 | 51 |
| Soybean | 68 | 38 | 46 | 19 | 43 |
| Mean | 74 | 52 | 39 | 33 | 50 |
| LSD 5% and 1% between spring crops means | | | | 19 and 27 | |
| LSD 5% and 1% between spring crops means | | | | 16 and 22 | |

Table 6. Visual score ratings of the effect of cover crops on shoot growth of couch grass in 1979 and 1982 at the end of the fall crop (after Paulos, 1987).

| Treatment (spring crops) | Treatment (fall crops) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Slashing** | | **Chickpea** | | **Lentil** | | **Linseed** | | **Mean** | |
| | **1979** | **1982**[1/] | **1979** | **1982** | **1979** | **1982** | **1979** | **1982** | **1979** | **1982** |
| Slashing | 7.0 | 6.8 | 5.2 | 2.3 | 5.0 | 2.5 | 4.5 | 1.8 | 5.4 | 3.3 |
| Noug | 4.0 | 2.9 | 1.5 | 1.3 | 1.5 | 1.0 | 1.2 | 1.0 | 2.3 | 1.5 |
| Bean | 4.8 | 4.3 | 2.8 | 2.8 | 2.5 | 3.0 | 1.8 | 1.5 | 2.9 | 2.9 |
| Soybean | 5.0 | 4.8 | 2.5 | 3.0 | 2.2 | 2.5 | 1.5 | 3.0 | 2.8 | 3.3 |
| Mean | 5.2 | 4.6 | 3.0 | 2.3 | 2.8 | 2.3 | 2.2 | 1.8 | 3.4 | 2.8 |

[1/] Values are visual scores of shoot growth on a scale of 0-7

| LSD ($P \leq 0.05$) | 1979 | 1982 |
|---|---|---|
| Between spring crop means | 1.04 | 1.59 |
| Between fall crop means | 0.94 | 0.89 |
| Between fall crop means for same spring crop | 1.69 | 0.89 |
| Between fall crop means for different spring crop | 1.69 | 0.89 |

Table 7. Effect of cover crops on dry weight yield of dry *Digtaria abyssinica* in grams at end of fall crop season (after Paulos, 1987).

| Treatment (spring crops) | 1981 season (fall crops) | | | | | 1982 season (fall crops) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Slashing | Chickpea | Lentil | Linseed | Mean | Slashing | Chickpea | Lentil | Linseed | Mean |
| Slashing | 2.21 | 1.89 | 1.86 | 1.03 | 1.95 | 2.04 | 2.04 | 1.08 | 1.75 | 1.91 |
| Noug | 1.69 | 0.92 | 0.93 | 0.78 | 1.08 | 1.69 | 1.38 | 1.40 | 1.01 | 1.37 |
| Bean | 1.77 | 0.72 | 0.98 | 0.60 | 1.02 | 1.95 | 1.76 | 1.48 | 1.91 | 1.59 |
| Soybean | 1.56 | 0.92 | 1.41 | 0.95 | 1.14 | 1.70 | 1.56 | 1.65 | 1.40 | 1.58 |
| Mean | 1.81 | 1.11 | 1.23 | 1.04 | 1.30 | 1.84 | 1.68 | 1.58 | 1.34 | 1.61 |

| | | |
|---|---|---|
| LSD 5% and 1% between spring crops means | 0.165 and 0.237 | 0.189 and 0.272 |
| LSD 5% and 1% between fall crops means | 0.174 and 0.250 | 0.217 and 0.312 |
| LSD 5% and 1% between fall crops means for same spring crop means | 0.350 and 0.504 | 0.434 and 0.623 |

[1] Values in each column represent transformed values.
[2] Each value also represent root mass collected from 5 randomly selected sites of 50 cm x 50 cm x 30 cm deep within a plot.

Table 8. Effect of controlling *Digtaria* by cover crops on the yield of Arabica coffee in 1980-1982 (Paulos, 1987).

| **Treatment (spring crop)** | **(fall crops)** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Slashing** | | | **Chickpea** | | | **Lentil** | | | **Linseed** | | | **Mean** | | |
| | **1980** | **1981** | **1982** | **1980** | **1981** | **1982** | **1980** | **1981** | **1982** | **1980** | **1981** | **1982** | **1980** | **1981** | **1982** |
| Slashing | 4.3 | 15.1 | 6.9 | 8.5 | 19.1 | 11.7 | 8.6 | 20.1 | 8.9 | 8.9 | 23.0 | 6.9 | 7.6 | 19.4 | 8.6 |
| Noug | 7.6 | 18.4 | 6.2 | 11.2 | 17.4 | 13.4 | 8.1 | 19.2 | 11.2 | 13.8 | 20.5 | 11.2 | 10.2 | 18.6 | 10.5 |
| Bean | 7.8 | 18.7 | 10.1 | 10.5 | 14.7 | 14.5 | 10.3 | 19.4 | 12.7 | 7.8 | 19.2 | 7.3 | 8.9 | 18.0 | 11.2 |
| Soybean | 8.7 | 20.7 | 7.5 | 10.7 | 19.5 | 12.1 | 8.5 | 22.6 | 8.5 | 7.4 | 22.4 | 7.8 | 8.8 | 21.3 | 9.0 |
| Mean | 6.9 | 18.3 | 7.7 | 10.2 | 17.7 | 12.9 | 8.9 | 20.1 | 10.4 | 9.5 | 21.3 | 8.3 | 8.9 | 19.3 | 9.8 |

LSD ($P \leq 0.05$)
1980 Spring crop mean = 3.2
Fall crop mean = 2.3
1981 and 1982 = NS (none significant).

## Chemical weed control

Herbicides will remain an essential part of coffee production, but their use need to be minimized to meet the demands of both farmers and the consumers. Much of the reduction can be achieved not only by reducing the number of applications but also by using a reduced dose appropriate to the situation in combination with other cultural practices. Tadesse (1998) reported several effective systemic and contact herbicides against the control of coffee weeds (Table 9). The effect of glyphosate on the control of couch grass (*Digitaria abyssinica)* applied at various growth stages was determined at Melko in the 1992 cropping season. The result revealed that couch grass was successfully controlled by the chemical applied at the weed growth stages of 15 and 25 cm heights as compared to 5 and 10 cm heights and the untreated check (Tables 10 and 11).

Table 9. Recommended herbicides for coffee weeds in Jimma area (after Tadesse, 1998).

| **Trade name** | **Common name** | **Rate (liter product /ha)** | **Mode of action** | **Target weeds** |
|---|---|---|---|---|
| Round-up | Glyphsate | 1-4 | Systemic | All weeds |
| Fusilade super | Fluazifop-buty1 | 2-4 | " | Grasses |
| Gramoxone | Paraquat | 1.5-2 | Contact | Broad leaf |
| Kalache 360 SL | Glyphosate | 1-4 | Systemic | All weeds |
| Glyfos 360 SL | Glyphosate | 1-6 | Systemic | All weeds |
| Clinic | Glyphosate | 1-4 | Systemic | Broad leaf |
| Touchdown Forte 360 SL | Glyphosate | 1-6 | Systemic | All weeds |
| Mamba 360 SL | Glyphosate | 1-4 | Systemic | All weeds |
| Glyphogan 480 SL | Glyphosate | 1-4 | Systemic | All weeds |

Table 10. Effect of glyphosate on underground root weight of couch grass at different growth heights (after Tadesse, 1992).

| **Herbicide (lit/ha)** | **Growth height (cm)** | | | | **Mean** |
|---|---|---|---|---|---|
| | **5** | **10** | **15** | **25** | |
| | **Underground dry weight (gm/plot)** | | | | |
| 0.0 | 330.0 | 388.3 | 416.7 | 453.3 | 402.1 |
| 2.0 | 290.0 | 240.0 | 161.7 | 178.0 | 217.4 |
| 3.0 | 285.0 | 236.7 | 151.3 | 173.2 | 211.5 |
| 4.0 | 273.0 | 228.3 | 150.0 | 163.5 | 203.8 |
| mean | 299.6 | 273.9 | 219.9 | 242.0 | |

LSD 5% and 1% between herbicide rates 11.00 and 16.70, between growth stages 9.64 and 14.60, between means of growth stages for the same herbicide rate 16.27 and 22.10, between growth stages for different herbicide rates 18.45 and 24.60.

Table 11. Effect of glyphosate on rhizome length of cough grass at different growth heights (after Tadesse, 1992).

| Herbicide ( lit. product/ha) | Growth height ( cm) | | | | Mean |
|---|---|---|---|---|---|
| | 5 | 10 | 15 | 25 | |
| | Underground dry weight (gm/plot) | | | | |
| 0.0 | 106.0 | 1250.0 | 132.0 | 124.0 | 121.75 |
| 2.0 | 85.0 | 63.0 | 33.0 | 38.0 | 54.75 |
| 3.0 | 83.0 | 64.0 | 29.0 | 33.0 | 52.25 |
| 4.0 | 82.0 | 60.0 | 31.0 | 35.0 | 52.99 |
| mean | 89.0 | 78.0 | 56.3 | 57.5 | |

LSD 5% and 1% between means of herbicide rates 8.2 and 11.7, between means of growth stages 9.3 and 12.6, between means of growth stages for the same herbicide rate 13.4 and 18.7, between means of growth stages for different herbicide rates15..4 and 29.1.

## Integrated weed management

Integrated weed management uses all available knowledge to manage weeds and prevent them from causing economic loss without adversely affecting the environment (Opile, 1995). Cover cropping, mulching, slashing, and digging, shading, proper land preparation methods and herbicides can be logically integrated depending on the environmental situation. Studies conducted at the Jimma Research Center (Melko) and Gera Sub-center indicated that integrating different weed control methods gave better weed control and increased coffee yield (Tables 12 and 13).

Table 12. Effect of IWM on coffee yield at Jimma (Melko).

| Treatment | Yield (Clean coffee Q/ha$^{-1}$) | | | | yield loss (%) |
|---|---|---|---|---|---|
| | 1995 | 1996 | 1997 | Mean | |
| 1 | 4.92 | 4.10 | 5.82 | 5.28 | 59.2 |
| 2 | 7.50 | 6.28 | 12.33 | 8.70 | 31.0 |
| 3 | 6.00 | 4.29 | 7.08 | 5.79 | 54.0 |
| 4 | 7.95 | 8.12 | 12.20 | 9.42 | 25.4 |
| 5 | 5.67 | 5.92 | 7.43 | 6.34 | 49.0 |
| 6 | 8.85 | 6.03 | 11.86 | 8.91 | 29.5 |
| 7 | 8.44 | 8.31 | 11.83 | 9.52 | 24.6 |
| 8 | 13.72 | 8.56 | 15.61 | 12.63 | - |
| 9 | 2.89 | 3.11 | 4.48 | 3.49 | 72.4 |
| LSD 5% | 2.5 | 2.0 | 5.21 | | |
| LSD 1% | 4.7 | 4.2 | 7.18 | | |

1=2-3 slashing; 2= 1 time roundup applied at 4 lt product ha$^{-1}$;
3=Noug cover crop applied at 20 kg ha$^{-1}$;
4= 1 slashing followed with roundup applied at 1lt product ha$^{-1}$,
5=1 slashing followed with noug cover crop at 20 kg ha$^{-1}$;
6= 1 roundup applied at 1.5lt ha$^{-1}$ followed with noug cover at 20 kg ha$^{-1}$;
7=1 slashing followed with roundup applied at 1.5lt ha$^{-1}$ followed by noug cover at 20 kg ha$^{-1}$;
8= Clean weeding; 9= 1 slashing (farmers practice).
Source: JARC progress reports of 1995-1997.

The treatment with coffee husk mulching was found to give better yield as compared to herbicide application, cover cropping and slashing (Table 13). This might be attributed to the contribution of the mulch in terms of water conservation and the nutrient obtained from decomposition of the mulch.

Table 13. Effect of integrated weed management on weed growth and coffee yield at Gera.

| Treatment | Weed dry weight ($Q/ha^{-1}$) | Clean coffee yield ($Q/ha^{-1}$) | | | | | Mean |
|---|---|---|---|---|---|---|---|
| | | 2001 | 2002 | 2003 | 2004 | 2005 | |
| 1. 1slashing/year (control) | 107.2 | 0.19c | 2.68e | 0.56e | 1.18d | 1.36 | 1.2 |
| 2. Cover crop only (62kg/ha) | 32.8 | 0.74c | 3.5de | 1.56e | 3.64d | 8.92 | 3.7 |
| 3. Mulch only (15-20 t/ha) | 159.3 | 2.10c | 7.10c | 4.85c | 8.85c | 8.80 | 6.4 |
| 4. Roundup 4 liters product /ha | 84.9 | 1.76c | 5.26cde | 2.68cde | 5.29cd | 6.30 | 4.3 |
| 5. Clean weeding | - | 7.40a | 15.46a | 13.92a | 25.39a | 12.50 | 15.0 |
| 6. Round up 2 liters /ha. + cover crop at 62 kg/ha | 42.2 | 1.74c | 6.42cd | 3.76cd | 8.53c | 9.40 | 6.0 |
| 7. Roundup 2 liters/ha + mulch at 15-20 t/ha | 78.8 | 5.40b | 7.78c | 8.70b | 15.7b | 11.60 | 9.8 |
| 8. Slash + cover crop + mulch + round up 2lt/ha | 5.6 | 5.00b | 11.18b | 13.0a | 29.6a | 17.50 | 15.3 |
| 9. Slash + cover+ mulch + roundup 1lt. /ha | 4.05 | 4.60b | 11.63b | 12.82a | 28.68a | 16.50 | 14.8 |
| 10. Slash + cover crop + mulch | 25.4 | 0.70c | 7.04c | 8.99b | 25.68a | 13.6 | 12.3 |

Means followed by the same letter within a column is not significantly different from each other (DMRT)
Cover crop= *Crotalaria zanzibarica*
Mulch = undecomposd coffee husk

# Conclusion and recommendations

Coffee is very slow growing perennial crop and, at the same time, the space between coffee trees is wide and remains open for quite a long period. These situations along with the conducive environmental conditions encourage fast weed growth. Perennial grasses and sedges can seriously compete with the crop and can deplete the essential elements such as nitrogen necessary for growth leading to stunted growth. Tremendous yield reduction can result if weeds are not controlled timely and adequately. It is advisable to use systemic herbicides such as glyphosate to control the perennial grasses and sedges during land preparation especially two weeks before planting coffee seedlings in the filed. Systemic herbicides such as glyphosate should be applied when the perennial grasses attain 15-30 cm height for effective control. Mulching coffee trees is also an important management practice and coffee husk at the rate of 15-20 tons $ha^{-1}$ is recommended. Crops such as chickpea, soybean, haricot bean, and noug

are suitable cover crops in coffee for suppressing weed growth and for generating additional income for the subsistent farmer. Nevertheless, since the growing condition under which the existing data has been generated has long been changed, weed research has to pursue this area of research and concentrate on identification of suitable crops to be used as cover crops in coffee. In addition, studies on seed rates, time of planting and fertilizer requirements of the cover crops are important. Generally, dependence on a single weed management practices is not advisable; hence, IWM would be the best strategy for sustainable coffee production.

## Gaps, challenges and prospects

- Intercropping has great contribution to weed management in coffee and economic advantage, (the space between the coffee bushes can be utilized for producing other crops). However, research information on suitable intercrops for coffee has not been generated so far. Hence, this area of research should be given due emphasis in the future.
- Mulching is important in weed control, soil moisture conservation, and addition of nutrients to the soil. However, suitable mulch materials have not been screened and identified for the different agro ecologies.
- Cover crops (live mulch) have great potential in suppressing weed growth specifically the hard to control perennial grasses and sedges in coffee. However, suitable cover crops have not been screened and identified for the different agro ecologies.

## Prospects

At present, although the advantages of IWM are well known, it is not widely practiced in the coffee growing areas. Hence, IWM would be the best weed management strategy for sustainable coffee production. Cover cropping, mulching, slashing and digging, shading, land preparation methods and herbicides can be logically integrated.

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# Weed Research on Fiber Crops in Ethiopia

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## Introduction

Cotton (*Gossypium hirsutum*) and Kenaf (*Hibiscus cannatinos*) are important fiber crops grown in Ethiopia. Cotton is the most valuable fibre crop. It is a source of raw material for the textile industry and seed cakes for animal feed. It is also an import substitute crop as well as a means of foreign currency earning. The total area under cotton production is not known, but the area under the former state farms was 42,584 ha. Currently this area is reduced to only 23,857 ha (USAID-Ethiopia, 1994). The yield potential of the crop largely depends on the kind of crop management practices employed. Therefore, there is a great variation in productivity between research-managed and farmer-managed fields. Under research, cotton yields range between 3.5-5.0 t $ha^{-1}$, but yields in commercial and smallholder farms are 2.0-3.0 and 0.5-1.0 t $ha^{-1}$, respectively (Esayas and Abraham, 2003). One of the major production/ management problems, which hamper the yield and quality of cotton, is of weeds. Cotton yield losses due to weeds may be severe, although the damage caused is not always as obvious as losses caused by other pests. Moreover, the degree to which weeds interfere with cotton growth and yield are dependent on the type of weed species, weed densities, weedy duration and environmental conditions. Because of its slower growth than weeds, cotton is more sensitive to weed interference than many other crops. In the Middle Awash Valley where cotton cultivation has been going on for a long time, a steady increase in weed population and occurrence of new weed species has been reported (Kassahun, 1998).

Kenaf is cultivated in many countries for making ropes and sacks but the crop can be used for manufacturing, among other things, papers and structural boards (Bedada, 1987; Parker, 1989). Hence, proper handling, packing and transportation of agricultural and industrial products demand an increased production of kenaf. However, the current kenaf production is far below the requirement, partly because of lack of improved cultural practices including weed control (Bedada, 1987; Dawit, 1988).

Despite the importance of weeds in these crops, research on weed control was limited, and the available information is scattered over unpublished reports. Hence, the objective of this paper is to review the available information on weed research in fibre crops, indicate gaps and challenges as well as suggest future directions.

## Research findings

Quantitative and qualitative surveys were conducted in the Middle Awash, Lower Awash, Humera and Metema cotton farms in 2000 and 2001 by the Werer Agricultural Research Center (WRC). During the survey, a total of 88 weed species belonging to 28 plant families were identified (Appendix 1)**.** Most of the species are erect annual herbs and grasses and the rest are perennial climbers and shrubs.

The frequency of occurrence of individual species ranged from 0.3 to 51.5%, while the infestation level ranged from 0.6 to 47.8%. Weed species with frequency and dominance levels below 5.0% and 0.05%, respectively, occurred rarely and at low density. There was a positive and significant relationship among the weed species frequency, abundance and dominance**.** The dominance level of individual weed species varied across locations and crop growth stages. Some weed species with high infestation levels at some localities were not important weeds at other localities. There were variations in weed species composition across locations and crop growth stages (Table 1). Survey results indicated that there were changes in the weed flora within the period of 10 years (1974 to 1984). The occurrence of new weed species was suggested to be due to the dissemination of weed seeds by the water used for irrigation.

Table 1**.** Similarity index (%) of weeds occurring in different cotton growing areas (after Abraham and Esayas, 2002).

| **Locations** | **Middle Awash** | **Lower Awash** | **Metema** | **Humera** |
|---|---|---|---|---|
| Middle Awash | 100 | 46 | 36 | 31 |
| Lower Awash | 46 | 100 | 30 | 44 |
| Metema | 36 | 30 | 100 | 42 |
| Humera | 31 | 44 | 42 | 100 |

Weeds were also found to harbour insects and diseases of crop plants. The broad leaf weeds *Gynandropsis gynandra* and *Portulaca oleracea* were found to be alternate hosts to the African bollworm (*Helicoverpa armigera*). Nematode gall was also observed on the roots of *Gynandropsis gynandra*, *Launea cornuta* and *Cyperus* species (Kassahun, 1989).

## Basic studies

Studies conducted for three consecutive years to determine the critical periods of weed competition in cotton at the Werer Research Center showed that the critical period of weed competition was between 30 and 60 days after crop emergence (DACE). The study also indicated that early weeding was important but not adequate (Tadesse and Ahmed, 1985). Early weeding up to 35 DACE was recommended to increase yield and reduce cost of weeding. The study also showed that late weeding reduced yield of seed cotton, while no weeding resulted in yield loss of 73%. Similarly, studies at the Abobo Research Centre (Gambela) indicated that the critical period of weed competition for cotton was between 30 and 60 DACE, and when no weeding was done an average yield loss of 74% was recorded (Table 2) (Aderajew and Mesele, 1993). A recent study conducted in 2001 and 2002 at WRC indicated cotton yield losses of 35-88% and 56-94% when weeding was delayed for 60 and 75 DACE, respectively. The loss ranged from 62-96% when no weeding was done. The critical period of competition was between 20 and 60 DACE (Abraham and Esayas, 2002; Esayas and Abraham, 2003).

Regarding kenaf, the study conducted on the frequency and time of weeding at the Bako Agricultural Research Center indicated that one or two times weeding within the first seven weeks at 20-25 and/ or 45-50 days after sowing was sufficient (Table 3). The shoot biomass weight of kenaf was reported to decline as weeding time was delayed. The yield loss due to uncontrolled weed competition was estimated to be 23% (Dawit, 1988).

Table 2. Effects of time and frequency of weeding on cotton seed yield and economic benefit at Abobo, Gambella (1988-1989) (after Aderajew and Mesele, 1993).

| Weeding (DACE) | Seed yield (t/ha) | Cost of weeding | Gross return | Net return |
|---|---|---|---|---|
| | | Birr /ha | | |
| Unweeded | 0.72 | - | 723 | 723 |
| 15 | 1.75 | 81 | 1746 | 1665 |
| 30 | 2.64 | 76 | 2643 | 2567 |
| 45 | 2.61 | 96 | 2599 | 2503 |
| 60 | 2.45 | 145 | 2453 | 2308 |
| 15 and 30 | 3.01 | 89 | 3014 | 2925 |
| 30 and 45 | 2.89 | 163 | 2895 | 2732 |
| 45 and 60 | 2.95 | 132 | 2954 | 2822 |
| 15, 30 and 45 | 3.18 | 209 | 3175 | 2966 |
| 30, 45 and 60 | 3.18 | 159 | 3117 | 2958 |
| Weed free check | 3.19 | 443 | 3192 | 2749 |
| Mean | 2.59 | 144 | 2592 | 2447 |
| C.V % | 13.71 | | | |

DACE = days after crop emergence

Table 3. Effects of time and frequency of weeding on fiber yield of kenaf at Anger (1982-1984) (after Dawit, 1988).

| Treatment | Yield (t/ha) |
|---|---|
| Unweeded | 2.1 |
| Weeded at 20-25 DACE | 2.7 |
| Weeded at 45-50 DACE | 2.8 |
| Weeded at 75-80 DACE | 2.2 |
| Weeded at 20-25 and 45-50 DACE | 2.5 |
| Weeded at 20-25 and 75-80 DACE | 2.3 |
| Weeded at 20-45,45-50 and 75-80 DACE | 2.6 |
| Mean | 2.5 |
| C.V | 21.0 |

DACE = days after crop emergence.

Esayas and Abraham (2003) found that cotton fibre quality parameters such as fibre fineness (which is read as the micronaire value), fibre maturity percent and 50% span length were affected when the cotton crop was subjected to different weed infestation periods of 15, 30, 45, 60, 75 and 90 DACE. Acceptable values for these quality parameters were recorded when the cotton crop was kept weed free for up to 45 DACE. Fibre span length (2.5%), fibre strength and fibre uniformity ratio were not affected.

# Control measures

## Cultural control

The value of appropriate cultural practices for weed control cannot be overlooked particularly in light of the high costs involved in the use of labour and herbicides and their unavailability (IAR, 1998; 1999; 2002). In the Middle Awash Valley, the tradition of herbicide use was not common, and weed control was mainly based on manual or mechanical inter-row cultivation and hand pulling. According to Esayas and Abraham (2003), trials conducted for three consecutive cropping seasons (2002-2004) to evaluate cultural practices that can control cottonweeds at WRC indicated that dry planting or pre-planting irrigation combined with machine or manual cultivations at about 15 to 20, 35 to 40 and 75 DACE provided effective results. Moreover, once manual cultivation was reported to be required at near harvesting stage of the crop to remove weeds that spoil lint quality.

## Chemical Control

Experiments conducted between 1995 and 1998 to evaluate pre- and post-emergence herbicides for the control of weeds in cotton showed that Propaquizafop at 2.0 L and Select at 0.4 L $ha^{-1}$ product were effective on grasses, and Metolachlor 960-EC at 2.5 L and Trifluralin at 2.4 L $ha^{-1}$ were

effective on both grasses and broad leaved weeds except *Cyperus* spp. (Abraham and Esayas, 2002; Esayas and Abraham, 2003; IAR, 1998; 1999; 2002; Kassahun, 1989; 1998). The cotton seed yields were high in the weed free check and two times hand-weeding treatments (Table 4).

Table 4. Effects of herbicide and hand weeding on weed infestation and cotton yield at Werer Research Center (1993-1994) (after Kassahun, 1998).

| Treatment | Rate (kg/ha) | GWCS* | | Yield (t/ha) |
|---|---|---|---|---|
| | | 20 DACE | 45 DACE | |
| Codal 400 EC | 6.0 | 1.0 | 1.5 | 4.3 |
| Metolachlor 960 EC | 2.5 | 1.0 | 2.5 | 3.9 |
| Trifluralin | 2.4 | 2.1 | 3.1 | 3.7 |
| Fluometuron | 4.0 | 2.8 | 4.2 | 3.2 |
| Fluzifop-butyl | 2.0 | 6.3 | 2.2 | 2.9 |
| Hand weeding 1x (30 DACE ) | - | 0 | 5.1 | 2.2 |
| Hand weeding 2x (30, 55 DACE) | - | 0 | 1.1 | 4.4 |
| Unweeded | - | 9.0 | 9.0 | 1.4 |
| C.V | | | | 9.8 |

*= general weed control score (1-9 scale): 1= effectively controlled, 9 = no effect.

# Conclusion and recommendations

- No weeding resulted in cotton yield losses of up to 96% in the Awash Valley. Yield loss due to weed competition in kenaf was as high as 23% indicating the need for serious research attention
- The critical period of weed competition in cotton was between 20 and 60 DACE
- Weed control by machine or manual cultivations at 15 to 20, 35 to 40 and 75 DACE are recommended for both farmers that use dry planting and pre-planting irrigation in cotton. In addition, single manual cultivation is recommended at near harvesting stage of the crop to remove weeds that spoil lint quality
- Post-emergence application of propaquizafop at 2.0 litres, select at 0.4 litre and fluazifop-butyl 15% at 1.5 Lha-1 product is effective against major grass weeds in cotton except sedges
- Pre-emergence application of Metolachlor 960 EC (at 2.5 L ha-1) plus one supplementary hand weeding (40-50 DAE) effectively controlled both grass and broad-leaf weeds and also significantly improved cotton seed yield
- For kenaf once or twice hand weeding at 20-25 and/ or 45-50 days after planting appeared to be sufficient
- The available cultural practices should be verified on large scale and promoted.

## Gaps and Challenges

- Lack of full time weed researchers working on fibre crops weed management
- Weed surveys, loss assessment, critical weed competition periods and weed control studies are lacking for many fiber crops growing areas in the country
- Studies on integrated weed management (IWM) practices are inadequate or lacking especially for noxious weeds such as *Cyperus*, *Prosopis*, and *Parthenium* etc.
- Little attention is given to studies on system analysis, appraisal of weed problems and farmers indigenous knowledge on weed management
- High incidence of shift in the weed flora resulting from weed carryover from the highlands to farms in the Awash Valley due to flooding of the Awash River
- The threat of alien invasive weed species and lack of awareness at points of introduction

# Prospects

A coordinated research effort to curb the problem of weeds in fiber crops production is critically important

- Quantitative and qualitative surveys should be launched, and loss assessment and critical period of weed competition studies should be done for major weeds before embarking on control measures
- Available research results on chemical and cultural weed control practices should be widely verified in different production areas
- IWM (integration of cultural, biological and chemical methods) studies should be conducted on economically important weeds such as Parthenium hysterophorus, Prosopis juliflora and Cyperus spp. both in irrigated and rain-fed fibre crop growing areas
- The efforts of breeders and physiologists in developing and evaluating agronomically competitive cultivars should be increased.

Table 1. Weed species recorded on cotton and kenaf in Ethiopia.

| Weed species | Importance | | References |
|---|---|---|---|
| | Cotton | Kenaf | |
| **Aizoaceae** | | | |
| *Zalya pentandra* | *xxx* | x | 3,12,17 |
| **Amaranthaceae** | | | |
| *Achyranthes aspera* | *x* | x | 12,15,17 |
| *Amaranthus hybridus* | *x* | x | 12,15,17 |
| **Asteraceae** | | | |
| *Bidens pilosa* | *x* | xx | 12,17 |
| *Blumea aurita* | *xx* | - | 15,16 |
| *Flaveria trinervia* | *xxx* | x | 12,17 |
| *Galinsoga parviflora.* | *xx* | xx | 12,15,17 |
| *Gnaphalium unionis* | *x* | x | 12,15,17 |
| *Guizotia scabra* | *x* | xx | 12,15,17 |
| *Launea cornuta* | *xx* | xx | 12,15,17 |
| *Parthenium hysterophorous* | *xxx* | xx | 14,17 |
| *Sonchus arvensis* | *x* | xx | 12,15,17 |
| *Tagetes minuta* | *xx* | xx | 12,15,17 |
| *Xanthium spinosum* | *xxx* | x | 3,12,15,17 |
| *Xanthium strumarium* | *xxx* | x | 3,12,15,17 |
| **Brassicaceae** | | | |
| *Raphanus raphanistrum* | *x* | xx | 3,12,15,16,17 |
| *Sinapis arvensis* | *x* | x | 12,17 |
| **Capparidaceae** | | | |
| *Gynandropsis gynandra* | *xxx* | xx | 12,17 |
| **Chenopodiaceae** | | | |
| *Chenopodium album* | *x* | xx | 12,15,17 |
| *Chenopodium ambrosiodes* | *x* | x | 12,15,17 |
| **Commelinaceae** | | | |
| *Commelina latifolia* | *xx* | xx | 7,12,15,17 |
| *Commelina benghalensis* | *x* | xx | 12,15,17 |
| **Caryophyllaceae** | | | |
| *Corrigiola capensis* | *x* | x | 12,15,17 |
| *Spergula arvensis* | *x* | x | 12,15,17 |
| **Convolvulaceae** | | | |
| *Convolvulus arvensis* | *x* | x | 5,12,16,17 |
| *Cuscuta campestris* | *x* | xx | 5,12,16,17 |
| *Cuscuta hyalina* | *x* | x | 12,17 |
| *Ipomoea aquatica* | *xxx* | x | 13,17 |
| **Cucurbitaceae** | | | |
| *Cucumis dipsaceus* | *x* | - | 12,16 |
| *Cucumis melo* | *x* | x | 12,16 |

Table 1. Contd.

| Weed species | Importance | | References |
|---|---|---|---|
| | Cotton | Kenaf | |
| **Cyperaceae** | | | |
| *Cyperus rotundus* | *xxx* | xx | 3,12,17 |
| *Cyperus bulbosus* | *xxx* | x | 3,12,17 |
| *Cyperus esculentus* | *xxx* | xxx | 3,12,17 |
| **Euphorbiaceae** | | | |
| *Euphorbia heterophylla* | *xx* | xx | 12,15,16,17 |
| *Euphorbia indica* | *x* | x | 12,15,16,17 |
| *Tragia plukenetil* | *x* | - | 12,15,16,17 |
| **Fabacea** | | | |
| *Alysicarpus glumaceus* | *x* | x | 10,16 |
| *Indigofera schimperi* | *x* | x | 10,16 |
| *Medicago polymorpha* | *x* | xx | 12,16,17 |
| *Prosopis juliflora* | *xxx* | xx | 14,17 |
| *Pseudarthria hookeri* | *x* | x | 10,16 |
| *Scorpiurus muricatus* | *x* | x | 12,16,17 |
| *Trifolium sp.* | *x* | x | 12,16,17 |
| **Lamiaceae** | | | |
| *Ocimum canum* | *x* | - | 12,16 |
| **Nyctaginaceae** | | | |
| *Boerhavia coccinea* | *x* | x | 12,15,16,17 |
| *Borehavia erecta* | *x* | x | 12,15,16,17 |
| *Borehavia repens* | *x* | x | 12,15,16,17 |
| **Orobanchaceae** | | | |
| *Orobance minor* | *x* | *x* | 3,16,17 |
| **Papaveraceae** | | | |
| *Argemone mexicana* | *x* | x | 12,17 |
| **Plantaginaceae** | | | |
| *Plantago lanceolata.* | *x* | x | 12,15,16,17 |
| *Plantago major* | *x* | x | 12,15,16,17 |
| **Poaceae** | | | |
| *Andropogan abyssinicus* | *x* | x | 13,17,20 |
| *Avena fatua* | *xx* | xx | 12,15,16,17 |
| *Bromus pectinatus* | *x* | x | 12,16,17 |
| *Cenchrus ciliaris* | *x* | x | 12,16,17 |
| *Cynodon dactylon* | *x* | x | 12,15,16,17 |
| *Digitaria scalarum* | *x* | x | 12,15,16,17 |
| *Dinebra retroflexa* | *x* | x | 12,15,16,17 |
| *Diplachne caudata* | *x* | x | 12,16 |
| *Echinocloa colona* | *xx* | xx | 12,15,16,17 |
| *Echinocloa crusgalli* | *xx* | x | 12,15,17 |

Table 1. Contd.

| Weed species | Importance | | References |
|---|---|---|---|
| | Cotton | Kenaf | |
| *Eleusine indica* | *x* | x | 12,15,17 |
| *Eragrostis aethopica* | *x* | x | 12,15,16,17 |
| *Eriochloa fatmensis* | *x* | x | 12,16,17 |
| *Hemarthria natans* | *x* | x | 12,16,17 |
| *Lolium temulentum* | *x* | x | 13,15,16,17 |
| *Panicum repens* | *x* | x | 13,15,16,17 |
| *Pennisetum* spp. | *x* | x | 13,15,16,17 |
| *Phalaris paradoxa* | *xxx* | xxx | 13,15,16,17 |
| *Poa annua* | *x* | x | 13,15,16,17 |
| *Setaria pumila* | *xxx* | xxx | 13,15,16,17 |
| *Setaria verticillata* | *xxx* | xxx | 13,15,16,17 |
| *Snowdenia polystachya.* | *xxx* | xxx | 12,16,17 |
| *Sorghum arundinaceum* | *xxx* | x | 13,15,16,17 |
| **Polygonaceae** | | | |
| *Polygonum aviculare* | *x* | xx | 12,16,17 |
| *Polygonum convolvulus* | *x* | x | 12,16,17 |
| *Polygonum nepalense.* | *x* | x | 12,16,17 |
| *Rumex abyssinicus* | *x* | x | 12,16,17 |
| **Portulaceae** | | | |
| *Portulaca oleracea* | *xxx* | x | 12,16 |
| **Primulaceae** | | | |
| *Anagallis arvensis* | *x* | x | 12,16,17 |
| **Rubiaceae** | | | |
| *Galium spurium* | *xx* | xx | 12,16,17 |
| **Solanaceae** | | | |
| *Datura stramonium* | *xx* | xx | 12,16,17 |
| *Nicandra physaloides* | *x* | x | 12,16,17 |
| *Solanum dubium* | *x* | x | 12,16,17 |
| *Solanum incanum* | *x* | x | 12,16,17 |
| *Solanum nigrum* | *x* | x | 12,16,17 |
| **Tiliaceae** | | | |
| *Corchorus olitorius* | *xxx* | x | 7,12,16 |
| **Zygophyllaceae** | | | |
| *Tribulus terrestris* | *xx* | x | 12,16,17 |

xxx = major weed, xx= important weed, x=commonly occurring, - = not reported.

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# Review of Research on Invasive Alien Weed Species in Ethiopia

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## Introduction

The increasing movement of different invasive alien species (IAS) through the aid of human and animals from place to place is causing a negative impact on socioeconomic, biological diversity, health and several aspects of the welfare of the people. The increasing human population, and the consequent pressure exerted on the natural resources of the country accelerated the change in land use patterns leading to conversion of a large mass of land to agriculture, mining, construction and other uses. These caused the natural ecosystem to be unsuitable for native biodiversity, providing an ideal opportunity for IAS to aggressively invade and expand their geographical dimension (Senayit et al., 2004; Taye et al., 2004c; 2004d).

As in many other countries in the tropics, invasive alien species were introduced to Ethiopia intentionally and unintentionally. In the absence of detailed background studies, prioritization of IAS was done by considering facts such as the magnitude of the invasiveness, threats to local biodiversity, socio-economic and human health impacts. Several alien species are reported to be spreading at alarming rate, threatening natural and agricultural ecosystems of the country. Currently, IAS is of a great concern posing serious problems to development, as well as big threat to biodiversity of the country. The environmental policy of Ethiopia (EPE), the research policy of the Ethiopian Institute of Agricultural Research (EIAR), and other policy and strategy documents acknowledge the eminent threat posed by IAS to the country's biodiversity and ecosystem at large (EARO, 2003; Ababu et al., 2004).

Among several IAS *Parthenium hysterophorus, Eichhornia crassipes, Prosopis juliflora* and *Lantana camara* are considered as emerging issues in this country. Parthenium is assumed to be introduced accidentally through aid shipments or from Somalia during Ethio-Somali war. Its impact in natural habitats has not been clearly assessed, but it clearly poses a major threat to rangelands and croplands. *Eichhornia crassipes* obstructs electricity generation, irrigation,

navigation, and fishing; increases water loss resulting from evapo-transpiration; and facilitates proliferation of diseases such as bilharzias. The introduction and rapid spread of this plant in the Awash River system since 1965 has caused serious problems in the use of the river (Tamado, 2001; Senayit et al., 2004). *Prosopis juliflora* was intentionally introduced as an agro-forestry species in the Awash basin, but now threatens the agricultural land and protected areas in the Awash National Park. It is aggressively invading pastoral areas in the middle and Upper Awash valley, and in eastern Hararghe destroying natural pasture, displacing native trees, forming impenetrable thickets, and reducing grazing potential of rangelands (Kassahun, 1996; 1999; Kassahun et al., 2004; Hailu et al., 2004).

In this review, attempts are made to provide information on the distribution of IAS, the different hazards caused viz. ecological, health and agricultural, biological and ecological characteristics, and the currently available control measures. Future prospects on IAS research and control in Ethiopia are also emphasized.

## Parthenium

Parthenium, *Parthenium hysterophorus* L., belongs to the family Asteraceae, an extremely diverse family with a cosmopolitan distribution (Parsons and Cutherbertson, 1992). It has been further classified under the tribe Heliantheae and sub-tribe Ambrosiinae. It is described as an annual, procumbent, diffused leafy herb with a height of 0.5 - 1.50 m, reaching a maximum of 2 m in good soils. Parthenium is commonly known as *parthenium weed* in Australia; *bitter weed, carrot weed, broom-bush,* and *congress weed* in India; *white top, escobar amarga* and *feverfew* in Caribbean; *false rag weed* and *rag weed parthenium* in USA (Navie et al., 1996). In Ethiopia, different vernacular names are used in different regions (Tamado, 2001; Taye, 2002; Rezene, 2005b). These include: *Qinche* (Tigray), *Qinche Arem*, *Chebehabe* (Amhara), *Terekabi* (Afar), *Kalignole* (Somalia region) and a variety of other names such as *Feremsisa, Arema Cuba, Biyabassa, Arema sorgo, Amamalee*, etc., in the Oromiya region. The names imply its introduction and/or invasiveness or morphology. For example, "*Arama Sorgo*" implies that the weed was introduced from Somalia during the Ethio-Somalia war in 1976/77. "*Biyabassa*" means leave the place or a region, "*Faramsisa*" means sign to leave the land, "*Qinche*" is a kind of food made of coarse grinned barley or wheat that looks like the white flowers of parthenium, and "*Kalignole*" means that lives alone indicating its allelopathic and strong competitive nature (Taye, 2002; Besufekad et al., 2005).

The centre of origin is thought to be central South America or the region surrounding the Gulf of Mexico (Navie et al., 1996; Kumar, 1998). In Ethiopia,

parthenium has become the worst weed since its discovery as exotic invasive weed in the 1980s. When and how it is introduced into the country is a matter of speculation. The first speculation was that seeds were brought into the country with imported grain donations for relief aid. The species was introduced into Ethiopia either through the Djibouti - Dire Dawa railway line or the Dire Dawa Air Port around 1980 (Mesfin, 1991). According to Parker (1988), the occurrence of the weed was observed for the first time around Dire Dawa, Harar and Meiso. Occurrence of the weed in South Wello starting from the air - strip in Kombolcha and settlement sites down to Jijiga (Frew et al., 1996) strengthen the view that the seeds of this species were brought into Ethiopia via the various food aid programs (Mesfin, 1991; Medhin, 1992). Another speculation suggests that its introduction to be during the Ethio-Somali war in 1976/77 along with the army vehicles (Frew et al., 1996; Taye, 2002). From the presence of parthenium in Kenya and Somalia (Njoroge, 1986) and the capacity of parthenium seed to travel long distances through wind, water and other means, it is also possible that parthenium could easily be introduced to Ethiopia from these neighbouring countries. The presence of *Puccinia abrupta* on parthenium in Ethiopia (Taye, 2002; Taye et al., 2004a) might also explain indirectly the introduction of parthenium from neighbouring countries, Kenya and/or Somalia, as the presence of *P. abrupta* was long known in Kenya (Evans, 1987). Although this observation confirms the entry and its escalation on a larger scale, so far there is no concrete justification with regard to the question of how and when it was introduced into the country (Taye, 2002).

## Distribution of parthenium

Parthenium is now widely spread in eastern Ethiopia; the Central Rift Valley and neighboring localities of Afar Region, East Shewa, Arsi and Bale in southern Ethiopia. It is spreading to areas closer to Addis Ababa, western part of Ethiopia; some districts in West Shewa, East and West Hararghe; South, North, and Central Tigray; North Gojam and South Gonder; North and South Wello. The weed is also spreading in series of small to large jumps to the southern regions of the country, notably areas around Hawasa, Jimma and Gambella (Tamado, 2001; Taye, 2002; Besufekad et al., 2005; Rezene et al., 2005a).

Taye (2002) stated that parthenium was detected as a major weed of crops in the North and eastern regions of Ethiopia with infestations greater than 20 plants per square meter in some localities. Infestation of parthenium in crop fields varied from field to field depending on the time of its introduction to the area and the efforts made to control it. High infestation of parthenium (> 20 plants/ $m^2$) was observed in sorghum fields around Kobo, and in sorghum, maize and tef fields around Robit, Gobie, Woldiya and Kombolcha, both during

the crop growing periods and after harvest. Similarly, in East Shewa (Wolenchitti, Wonji, Metahara), Afar (Awash, Anano, and Miesso), and West and East Hararghe, aheavy infestations of sorghum and maize were observed during the fallow and cropping seasons.

In the central farmlands of East Shewa: Dukem, Debre Zeit, Mojo, and Koka areas heavy and widespread infestation occurs mostly on roadsides, wastelands, towns, villages and gardens. In Ziway, Hawassa and Wolkite, the weed was observed only in the towns along the road and near dwellings indicating its recent introduction into the area. In many districts of West Shewa: Shoboka, Tibe, Guder, and Wolliso, only localized infestations in crop fields were observed indicating its recent introduction to these areas (Taye, 2002). Tamado (2001) carried out surveys in 240 crop fields in eastern Ethiopia and reported that the two most frequent species were *Digitaria abyssinica* (63%) followed by parthenium (54%). The latter was ranked as the most important weed by 90% of the farmers in the lowlands while 86% of the farmers in the highlands ranked the former species as the worst weed. Altitude, rainfall, month of planting, number of weeding and soil types were the major environmental/crop management factors influencing the species distribution in the study area. Rezene et al. (2005a) reported the spread and infestation of parthenium from different Zonal and District Agricultural Bureaus of the Oromia, Amhara and Tigrai Regional States (Tables 1, 2 and 3). Both cultivated and grazing lands were reported to be abandoned in many localities (Rezene et al., 2005a).

The occurrence of the weed in grasslands is reported to reduce forage production up to 90%, in addition to its negative effects on animal health, and milk and meat quality (Evans, 1997; Navie et al., 1996). Moreover, it suppresses and replaces natural vegetation in a wide range of habitats due to its allelopathic potential, thus, is a serious threat to biodiversity (Senayit et al., 2004; Taye et al., 2004c; 2004d). Very little or sometimes no vegetation could be seen in parthenium-dominated areas. Wherever it invades, it forms a territory of its own replacing the indigenous grasses and weeds. Parthenium is rarely seen in well cultivated fields. However, its problem persists in poorly managed fields, broad spaced crops, in plantations, and grasslands. The problem is more serious in non-crop areas, neglected fields, along fence lines, irrigation or drainage ditches and wastelands. While some measures of control is adopted by farmers in farmlands, the problem in wastelands and in public places, roadsides and railway tracks where it is most serious is not tackled by anybody.

Table 1. Spread and status of parthenium infestation in the Oromiya, Amhara and Tigrai Regional National States (after Rezene et al., 2005a).

| Woreda (district) | Record of initial infestation | | Infestation level | Areas infested |
|---|---|---|---|---|
| | Year | Place | | |
| **West Hararghe** | | | | |
| Mesela | 1988 | Roadside | High | 1,2,3,4,5,6,7 |
| Doba | 1990 | NR | High | 1,2,3,4,5,6,7 |
| Ciro | 1989 | Roadside | High | 1,2,3,4,5,6, |
| Xulo | 1988 | Hirna town | High | 1,2,3,4,5,6,7 |
| Darolebu | 1987 | Mechara | High | 1,2,3,5,6,7 |
| Kuni | 1979 | NR | High | 1,2,3,4,6,7 |
| Goba Koricha | 1980 | NR | High | 1,2,3,4,5,6,7 |
| Mieso | 1985 | Roadside | High | 1,2,3,4,5,6,7 |
| Habro | 1987 | NR | High | 1,2,3,4,5,6,7 |
| **East Hararghe** | | | | |
| Kurfachelie | 1985 | Roadside | Low | 2 |
| Melka Bolo | 1989 | Roadside | High | 1,2,3,4,5,6,7 |
| Kombolcha | 1991 | Roadside | High | 1,2,3,4,5,6 |
| Jarso | 1990 | Roadside | High | 1,2,3,4,5,6,7 |
| Alemaya | 1995 | Roadside, grazing land | High | 1,2,3,4,5,6 |
| Babilie | 1977 | NR | High | 1,2,3,4,5,6,7 |
| Dedder | 1996 | NR | High | 1,2,3,4,5 |
| Kerssa | 1988 | NR | High | 1,2,3,4,5,6 |
| Bedeno | 1987 | NR | High | 2,5 |
| Gurogutu | 1977 | NR | Low | 1,2,3,4,5 |
| Goloda | 1990 | CARE Store | High | 1,2,5,7 |
| Gursum | 1978 | Jijiga road | High | 1,2,3,4,5 |
| Meta | 1985 | Roadside | High | 1,2,3,4,5,6,7 |
| Girawa | 1977 | NR | Low | 2,4,5,7 |
| Fedis | 1977 | NR | High | 1,2,3,4,5,6,7 |
| **East Shewa** | | | | |
| Boset | 1991 | NR | High | 1,2,3,4,5,6,7 |
| Lumie | 1993 | NR | High | 1,2,3,4,5,6,7 |
| Adaliben | 1989 | Roadside | High | 1,2,3,4,5,6 |
| Fentalie | 1996 | NR | Medium | 1,3,7 |
| Akaki | 1994 | Roadside | Medium | 2,5,6,7 |
| **West Shewa zone** | | | | |
| Woliso | ? | NR | Low | 1,2,3,4,5,6,7 |
| Ambo | 1997 | NR | Medium | 1,2,3,4,5 |
| Tolie | 1994 | Roadside | Medium | 1,2,3,4,5,6 |
| Ameya | ? | NR | Low | 2,5 |
| Becho | ? | Roadside | Low | 1,2,3,4,5 |
| **Arsi zone** | | | | |
| Hetosa | 1998 | NR | Low | 1,2 |
| Merti | 1993 | Town area | Medium | 1,2,4,5,6,7 |
| Dodota Sire | 1989 | NR | Medium | 1,2,3,5,6,7 |

Table 1. Contd.

| | | | | |
|---|---|---|---|---|
| **Bale Zone** | | | | |
| Ginir | 1997 | NR | Medium | 1,2,5 |
| Mena | 1998 | NR | Medium | 2,6,7 |
| **Illbabor zone** | | | | |
| Darimu | 1988 | Market area | Low | 6 |
| Haluburie | 1997 | Market area | Low | 3, 6 |

NR = not recorded, areas infested 1 = cultivated, 2 = roadside, 3 = grazing, 4 = non-cultivated, 5 = rural villages, 6 = urban areas, and 7 = riverside,? = unknown.

Table 2. Spread of parthenium in the Amhara Regional State (after Rezene et al., 2005a).

| **Zonal Administration** | **No. of infested** | | **Area infested (ha)** |
|---|---|---|---|
| | **Woredas (district)** | ***Kebeles* (PA)** | |
| Wag Hamra | 2 | 9 | 62.5 |
| North Wollo | 5 | 81 | 34,134.0 |
| South Wollo | 6 | 42 | 1,671.0 |
| Oromia | 4 | 23 | 649.0 |
| North Shewa | 7 | 42 | 532.0 |
| West Gojam | 3 | 4 | 55.0 |
| Awi | 1 | 1 | 0.125 |
| South Gonder | 1 | 3 | 1.5 |
| Total | 29 | 205 | 37,105.0 |

Table 3. The status of parthenium in Tigrai Regional State (Rezene et al. 2005a).

| **Woredas** | **No. of Pass** | **Area coverage (ha)** | | | | |
|---|---|---|---|---|---|---|
| | | **Crop land** | **Forest area** | **Urban areas and roadsides** | **Riverside** | **Total** |
| Alma-Ata | 11 | 10,000 | 52.0 | 58.0 | - | 10,110 |
| Ray Azebo | 12 | 110.5 | 29.75 | 20.0 | 83 | 243.25 |
| Ofla | 2 | - | - | 8.75 | - | 8.75 |
| Endamehoni | 1 | - | - | 5.0 | - | 5.0 |
| Enderta | 1 | - | - | 1.5 | - | 1.5 |
| South Tembien | 3 | 53 | 2.50 | 1.85 | 36.50 | 93.85 |
| Upper Maichew | 1 | 8 | - | 2.0 | - | 10.0 |
| Ahferom | 1 | - | - | 0.062 | - | 0.062 |
| Mereb Lehe | 1 | - | - | 0.005 | - | 0.005 |
| Adwa | 1 | 0.50 | - | 2.5 | - | 3.0 |
| Tahtay Keraro | 1 | - | - | 0.063 | - | 0.63 |
| Wukro | 1 | .0004 | - | 0.274 | - | 0.274 |
| Ganta Afeshum | 1 | - | - | 0.25 | - | 0.25 |
| T/Abergele | 1 | - | - | 8.0 | - | 8.0 |
| H/Wajrat | 1 | - | - | 0.5 | - | 0.50 |
| Mekele | 20 | - | - | 10.0 | - | 10.0 |
| Total | 59 | 10,172 | 84.25 | 118.75 | 119.5 | 10,495 |

PAs = Peasant Associations.

## Ecology of parthenium

In Ethiopia, the weed grows in different habitats from hot arid and semi-arid low altitude to humid high-mid-altitude (900 - 2500 m). It grows on any type of soil and different habitats (Taye, 2002). The crops infested include maize, sorghum, finger millet, cotton, haricot bean, tef, potato, tomato, onion, cabbage, carrot, citrus, mango, papaya, and banana (Taye, 2002). It was noted that the weed population was high in places where the soils are disturbed constantly for purposes of construction of roads and buildings. Therefore, the extensive dense stands along roadsides in Ethiopia might be due to the routine disturbance and grading of road verges and transportation of sands and gravel from parthenium infested to non-infested areas (Fasil, 1994; Taye, 2002). The spread of the plant onto large areas of grazing land might also be due to severe overgrazing of natural pastures which provide suitable conditions for the weed. It forms extensive stands in grasslands and gardens where the land is overgrazed or mechanically cleared of natural vegetation because the disturbance of the vegetation allows parthenium to be the first coloniser of the land. Hence, proper management of the grazing land and development of the vegetation stand in disturbed areas is mandatory to reduce its infestation (Taye, 2002). In crop fields, it can be eliminated along with the regular weeding process (hand pulling and/or hoeing) where intensive cultivation is practised as observed in West and East Hararghe. However, it grows profusely on the field borders and roadsides from which re-infestation takes place. Parthenium has been observed in the field germinating and growing alone even during dry periods with one or two showers. This might be due to its relatively little moisture requirement for germination and its drought resistance capacity thereby suppressing other plant species (Taye, 2002). The lowest mean minimum temperature where parthenium grows was 4°C at Alemaya during the month of December and the highest mean maximum temperature was 35°C at Dire Dawa during the months of April to May. However, the infestation was very low at high altitudes and was not observed on mountains. This may be due to low temperatures. The annual mean precipitation in the survey areas ranges from 805 mm at Alemaya to 1389 mm in Wolkite (Taye, 2002).

## Germination ecology

Tamado (2001) conducted series of laboratory and greenhouse experiments on the germination response of parthenium seeds to important physical and climatic factors influencing seed survival, germination and emergence in the field. He reported that freshly-harvested seeds required light for germination. However, after one month of seed burial in the soil, the percentage of germination increased both in light and in darkness. Hence, it seems that parthenium has seeds that are initially dormant. Viability of the seeds was greater than 50% after 26 months of burial and predicted the half-life of seeds

in the soil to be approximately 3 to 4 years. This indicates the potential for build-up of massive soil seed bank and the difficulty of its eradication. Seeds buried in the soil showed higher germination as compared to seeds dry-stored possibly due to alternating temperature, moisture, chemical or biological factors operating in the soil. There were no strong seasonal changes observed in dormancy in this study (Tamado, 2001). It was also reported that seeds can germinate during any time of the year over a wide range of both constant (10°C and 25°C) and fluctuating (12/2°C to 35/25°C) temperatures, if moisture is not limiting. The rate of seed germination was high and fast at higher temperatures. Under moisture stress the weed seeds showed lower rate of germination than sorghum, and the effect of moisture stress was more severe at higher temperature (27°C). This implies the earlier emergence of sorghum in the field than parthenium in response to lower precipitation. Naturally dispersed seeds required about 60 days to start emergence in the field despite the presence of adequate rainfall. This delay in emergence may be due to the need for after-ripening period in order to reduce dormancy. Thus, farmers can utilize this delay and adjust sowing date for their crops so as to suppress the weeds. Maximum emergence of parthenium occurred from shallowly buried (0.5 cm) seeds and emergence decreased with increased depth, possibly due to exhaustion of seedling reserves before emergence or induction of dormancy. Light was not essential for triggering germination in the buried seeds. The study also indicated that burial of parthenium seeds to a depth of 7 cm or more by ploughing or hand hoeing can temporarily prevent seedling emergence.

## Growth response and competitiveness of parthenium

Growth responses of parthenium and grain sorghum to shade, watering frequency and fertilizer application were studied in monoculture and in additive mixtures (Tamado, 2001). Shading reduced dry weight, height and root to shoot ratio of parthenium, while grain sorghum was less affected. Maximum dry weight of both species occurred in the wettest (4 day watering) treatment on sandy soil and in moderate (6 and 8 day) watering frequencies on loam soil. However, the effect of imposed water stress on a mixed culture was not consistent. Fertilization increased the dry weights of both species in monoculture. However, in mixed stands, dry weight of parthenium declined and very few plants managed to flower at the highest fertilizer rate (200 kg DAP/ha), possibly due to an increased suppressive effect from the associated sorghum. Increasing the rate of fertilizer application to sorghum can thus be an indirect method of controlling the weed. According to Tamado et al. (2002), sorghum yield loss due to given densities of parthenium in field experiments highly varied with sites and years, ranging from 40-97%. Similarly, the critical periods for its control were highly variable, the greatest range being from emergence of sorghum to 66 days. Though it was not possible to give accurate

recommendations on threshold densities and critical periods due to variations in yield and yield loss between sites and years, it is advised to prevent early establishment of the weed to give a competitive advantage to the crop.

## Parthenium *c*ontrol

### Cultural and chemical control

Manual labor is the most widely employed control practice by farmers to manage the weed in agricultural land. As the weed causes contact dermatitis, asthma and fever to human beings, hand weeding is not advisable for Parthenium sensitive people (Fasil, 1994; Navie et al., 1996). Besides, hand weeding is costly, as it requires frequent operations owing to the emergence pattern of the weed. Hoeing can also be used but repeated operations are needed as long as weed seeds exist in the soil. Taye (2002) stated that the control of parthenium is entirely based on cultural and labour intensive practices such as tillage, hand weeding, mowing, hoeing and slashing. Unlike large-scale farms, small-scale farmers prepare their lands using repeated oxen ploughings and/or hoeing. Because of its extended tap-root system deep into the soil, mature plants of parthenium are difficult to uproot. Hence, ploughing aimed at the control of parthenium should be done at its early period of growth. Most farmers were observed to mow infested fields at first and then plough using oxen. Uprooting is difficult unless ploughing is done at the time when there is enough moisture in the soil. In the eastern parts of Ethiopia, intensive hand weeding and/or hoeing are practised in crop fields like maize, sorghum, chat, etc. By so doing, farmers keep their crop fields almost free from parthenium, though some farmers reported to suffer from arthenium allergy, fatigues, headaches, and fever. Farmers do not realize the importance of weeding parthenium from field borders, vacant sites and grasslands. Hence, from these areas originates re-infestations and spread to other areas. In some cases, farmers are advised by the technology extension group from the Ministry of Agriculture and Rural development to eradicate by mowing and slashing Parthenium growing in their village, garden, fields, roadsides, and grasslands through campaigns.

Besufekad (2005) reported that the use of intercropping in sorghum reduces vulnerability of the crop to the weed and guarantees higher crop yield. Cowpea intercropped with sorghum + pre-emergence application of pendimethalin @ at 1.0 kg/ha appeared most promising in terms of suppressing the growth of parthenium and improvement in sorghum yield. Tamado (2001) also reported that growing cowpea as smother crop reduced parthenium weed, but depressed sorghum grain yield in eastern Ethiopia possibly due to low soil moisture that could not meet the combined demand of both the cowpea and sorghum. Hand

hoeing twice gave a better sorghum yield than smoother crop or using a herbicide (2,4-D). Integrated use of deep ploughing, use of more competitive varieties, choice of appropriate sowing rate and date, and use of an appropriate smother crop or intercrops is recommended.

## Biological control

The pathogens associated with parthenium in Ethiopia were studied by several workers (Taye, 2002; Taye et al., 2004a; 2004b). The fungal flora isolated from seeds, floral parts and leaves from different locations consisted mostly of saprophytic fungi, *Penicillium, Aspergillus, Alternaria,* and *Cladosporium* species. Putative fungal isolates of *Phoma, Helminthosporium, Curvularia, Chaetomium, Eurotium* and *Fusarium* species were selected for pathogenicity tests. However, most of these isolates did not show pathogenic effects while a few showed non-specific symptoms on the weed. Only one isolate, *Helminthosporium* sp., obtained from a fruit farm at Shewa Robit resulted in a leaf blight symptom similar to the infected samples collected from the field. Nonetheless, repeated inoculation tests of this isolate showed that its virulence was limited and requires high humidity (> 90%) for infection to occur. It was concluded that these pathogens could be opportunistic with insignificant potential for biological control. It is more likely that parthenium is a secondary host, and serve as a source of inoculum for crop diseases (Taye, 2002).

The pathogen that causes rust on parthenium in Ethiopia was identified as *Puccinia abrupta* Diet. and Holw. var. *partheniicola* (Jackson) by Parmelee in 1967 (Taye, 2002; Taye et al., 2004a). It was found infecting leaves, stems, and floral parts of parthenium in cool and humid areas of Ethiopia. Symptoms on the plant revealed chlorosis, necrosis, and reduction in vegetative growth, and seed production. Host specificity of *Puccinia abrupta* on related crop and weed species showed that its sporulation was observed only on parthenium. However, limited numbers of poorly developed pustules were observed on 3 varieties of Niger seed (Kuyu, Fogera and Esete). No disease symptoms were observed on all other crop and weed species tested. Hence, they were rated as immune or highly resistant. Subsequent to host specificity test, the effect of rust on morphological parameters and seed production capacity showed that mean plant height, number of leaves per plant and number of branches per plant of parthenium were significantly affected by the rust. Dry matter yield at maturity and mean number of seeds per plant were significantly reduced by 24 - 46%. However, a mycoparasite of rust fungi (Uredinales), *Sphaerellopsis filum* (Biv. Ex. Fr.) B. Sutton [*Darluca filum* (Biv. Ex. Fr.) Castagne] was found associated with the uredospores of the rust. This mycoparasite was reported to affect the growth and sporulation of the rusts. The hyphae, pycnidia, and conidia of the parasite were observed in the uredospores collected from the field and

germinating spores of *P. abrupta* under the light and scanning electron microscope (Taye, 2002; Taye et al., 2004a). Phyllody infected plants of parthenium are characterised by their excessive branching, reduced plant height, and transformation of floral parts into many small green leaf-like structures that lead to sterility of plants. Moreover, the diseased plants often formed rosette-like structures through the production of stunted axillary shoots from the crown or nodes of the stem (Taye, 2002; Taye et al., 2004a). The authors recommended that continued effort is necessary in order to identify the parthenium phyllody vector(s) through feeding test and detection of phytoplasma agent from different suspected insect vectors.

Parthenium plants with phyllody symptom were fixed, embedded and ultrathin stem sections of 200-300 nm were observed under transmission electron microscope. Phytoplasma-like bodies of different sizes and shapes were detected. Becke (2005) detected parthenium phyllody from groundnut and sesame in Ethiopia. Results of molecular analysis indicated that sesame and groundnut crops are likely to be infected by the parthenium phyllody causing pathogen. Hence, the phytoplasma can be reliably diagnosed with DNA techniques. Taye et al. (2004b) reported the effect of the phyllody disease on morphological parameters at flowering at three locations: Debre Zeit, Fedis and Dire Dawa, and found that mean plant height, leaf length, leaf width and leaf area were significantly reduced, while mean number of leaves per plant and number of branches per plant were significantly increased due to phyllody disease. Mean plant height was reduced by 31, 29 and 27% at Debre Zeit, Fedis and Dire Dawa, respectively, as compared to healthy parthenium plants. Similarly, leaf area was reduced equally by 82% at Debre Zeit and Fedis and by 80% at Dire Dawa. Dry matter yield at maturity was increased by 6, 8 and 31%, respectively, at Debre Zeit, Fedis and Dire Dawa. But, seed production was reduced by 91, 85, and 78%, respectively, indicating the importance of phyllody disease in reducing the reproduction capacity of the weed.

Surveys conducted to determine the occurrence and distribution of parthenium rust diseases during the cropping and off-seasons indicated that the incidence of the disease varied from 0 to 100%. The highest incidence (>50%) was observed in Mersa on roadsides and in Kombolcha in the town, roadsides and in maize fields after harvest in January 2000. In Weldiya, Addis Mender, Ambo, Hirna, and Kersa the rust incidence was 21-50% both on roadsides and in crop fields after harvest in January 2000 (Taye, 2002; Taye et al., 2004a; 2004b). The disease was observed in all areas surveyed except in Sibu Sire, Shoboka, Ambo, Wolliso, Tullubollo, Akaki and Koka. The highest incidence of phyllody disease (>50%) was recorded from Robit, Gobiye and Weldiya in North Wollo during October 2000, and from Anano area in Afar both during crop growing and fallow periods. Incidences ranging from 21-50% were recorded from Kobo,

Kombolcha, Addis Mender, Mojo, Nazareth, and Kulubi during the cropping season only, while in Metahara, Awash, Miesso, and Dire Dawa during both cropping and fallow periods. In other areas, the percentage of incidence ranged from 6-20%. It seems that phyllody disease is more prevalent in arid and semi-arid low altitude areas than humid cool altitudes. In some areas like Ambo, parthenium phyllody was not observed, though the temperature and rainfall are similar to phyllody prevalent areas. The absence of phyllody in some areas may be due to the absence of insect vector(s) that transmits phyllody or else collateral host(s) in the area (Taye et al., 20004b).

## *Prosopis juliflora*

*Prosopis juliflora (Swarz*) DC is a perennial thorny deciduous shrub or a small tree weed belonging to the family Leguminose. It was described in Ethiopia by different authors as large crowned evergreen tree with a deep taproot and a well-developed lateral root system; height ranges between 1-18 meters, depending on the type of soil in arid and semi arid conditions (Hailu et al., 2004; Kassahun et al., 2004). The plant is native to North and Central America (Asfaw et al., 1989; Hailu et al., 2004; Kassahun et al., 2004). The genus comprises 44 species (Burkart, 1976) of which only one is introduced to Ethiopia. They are extensively planted as fast-growing and drought tolerant fuel and fodder trees, but in many countries they have also spread out of control as invasive weeds. Prosopis has been introduced to and become naturalized in the tropics where it is cultivated for shade, timber, forage, food and medicine (Asfaw et al., 1989; Kassahun et al., 2004). However, contrary to the purpose of its introduction in different countries, it has escaped cultivation and proved to be a severe invader of farmlands, irrigation schemes, rangelands, etc.(Mohamed, 1997).

The exact date and means of introduction in Ethiopia is not clearly known, but different speculations exist. According to the local people, it was introduced deliberately but unauthorized by a British man called William Ulcro who was in charge of the Middle Awash Irrigation Project (Kassahun, 1999; Kassahun et al., 2004). It was supposed to have been introduced in 1972. The authors described that prosopis seeds were planted with the consent of the local elderly who were told about its benefit. The Amibara Irrigation Project area is considered as the starting point for the spread of prosopis (Hailu et al., 2004; Kassahun et al., 2004). Animal tethering spots of the mobile nomads served as a means of long distance spread and pioneer for the invasion of new areas. Appearance in farms and rangelands started 15 years ago. Seed dissemination via livestock faeces (goat, cattle, camel, sheep, wild herbivores, etc.) is a major means of dispersal. The camel-goat system to which prosopis was introduced assisted the spread and germination to the extent that the plant has become out of hand. Irrigation water is also another means of seed dissemination. Spread is

increasing both in area coverage and plant density per unit area at an alarming rate in the last decade. As a result, large tract of potentially irrigable alluvial soil and rangelands are at risk from prosopis invasion (Hailu et al., 2004; Kassahun et al., 2004).

## Distribution

Prosopis has an aggressive invasive character invading pastureland, irrigated lands and irrigation canals causing an irreversible displacement of natural pasture grasses as well as native tree species (Kassahun et al., 2004; Senayit et al., 2004). It is now a common sighting from Awash Arba all the way to Dire Dawa and Harar. Infestations typically originate from the many small villages, extending along the main routes and are now steadily advancing into the surrounding landscape. This corresponds with movements of animals being driven to markets and nomadic settlements. It has also spread to cultivation areas and flood plains along the river Awash, which is of high economic importance to the region (Senayit et al., 2004). Of grave concern is the fact that this river transects the entire region, putting many high potential irrigation areas further downstream at risk. The naturalized extent of invasion is unknown at this stage, but is estimated to be the order of 4000 ha. Invasions of prosopis were also reported in the town of Arba Minch and neighboring localities in the southern parts of the country (Rezene et al., 2005a). Contrary to the purposes of its introduction, prosopis is rapidly invading the traditional agro- and silvo-pastoral land of the Afar and Isa ethnic groups in the Afar National Regional State and has encroached hundreds of kilometres away from the initial plantation area (Hailu et al 2004, Senayit et al 2004).

The species introduced to Ethiopia is known for its numerous harmful effects on the livelihood of the local people. These include loss of natural pasture, displacing of native trees, reduction in stocking rate, toxicity to livestock, formation of impenetrable thickets and increased incidence of crop pests (Senayit et al., 2004; Taye et al., 2004c). Coppices forming impenetrable thicket prohibits free movement of cattle. Thorns damage eyes and hooves of camels, donkeys, and cattle with poisons eventually leading to death of the animals. The invasiveness of the species seems to have been further aggravated by overgrazing /browsing of rangelands and deforestation of native tree species. This plant is invading potential croplands forcing local farmers with less capital and machinery for clearing to abandon their farmland. The cost of clearing fallow land left for reclamation is also increasing for large-scale commercial farms. The biggest challenge, however, comes from the invasion of the main and secondary irrigation canals by its dense stand. This limits the visibility and accessibility to the irrigation canals for supervision and maintenance resulting in flood hazard and wastage of irrigation water through seepage. The irrigation

project is spending a total of birr 150,000 annually for clearing the main irrigation canals which needs twice bulldozing. This cost does not include the expense of clearing secondary and tertiary canals. It has also increased the incidence of cotton pests such as aphids and spider mites by serving as an alternate host. The invasion of air strips and field borders by prosopis has prohibited the use of aircraft for cotton pesticide spray (Kassahun et al., 2004; Senayit et al., 2004).

## Biology and ecology

Hailu et al. (2004) made a detailed study that focused on the number of seeds produced in a pod, seed dispersal through droppings of animals, soil seed banks, seed germination and stumping height of trees and the coppicing ability of prosopis. The results indicated that the mean number of seeds/pod was 24; seed size was (0.8-1.7cm) x (8-29 cm); and the mean weight of a seed was about 0.028 g. The number of seeds recovered from 1 kg of droppings of goats, camels, warthogs and cattle ranged between 760-2833 suggesting that cattle are the major dispersers followed by warthogs, camels and goats. There was a highly significant difference in vertical distribution of seeds recovered from soil samples. Soil seed density decreased as soil depth increased and vice versa. The horizontal distribution also exhibited a great disparity in density of soil seed samples which indicates that the density of seeds decreased from the highly invaded area to the less invaded area along the line-transects. Germination of seeds of prosopis differed significantly among the various treatments. The highest rate of seed germination (100%) was obtained from seeds that were treated with mechanical scarification, and sulfuric acid treatment for 15-60 minutes (97-100%), while seeds treated with dry heat at 120°C showed least germination (0-1%). About 37% of the seeds recovered from droppings of goats and 47% from warthogs were germinated. The mean number of coppices produced 6 months after stumping was 17.8 with a mean height of 68.4 cm.

Prosopis has the characteristics of 1) producing many, small and hard seeds capable of surviving passage through the digestive system of animals, entering into the soil to form soil seed banks and remaining viable until favorable conditions are there for germination; 2) attracting and rewarding pods for animals, containing fleshy and sweet mesocarp, that is meant for long-distance dispersal; 3) accumulation of dormant but long-lived viable seed reserves that would serve as sources of regeneration; 4) production of a mixture of seeds, with few capable of germinating immediately after dispersal while others remain dormant; 5) great ability to re-sprouting and fast coppice growth from stumped trees, making it a very strong competitor invader combined with its sexual reproduction. Combinations of all these characteristics make prosopis a powerful noxious invader. Invasiveness of the species is further enhanced

because of poor management practices on arable and rangelands. In some areas, prosopis has spread from the low rainfall zones in which it was planted, to watercourses, irrigated agricultural land, and adjacent higher rainfall areas. In Ethiopia, the presence of strong poisonous thorns and bushy growth habit of *Prosopis* makes it less attractive and inconvenient for human interference reducing the impact of deforestation (Senayit et al., 2004).

## The advantages of prosopis

*Prosopis* s*pecies* provide many of the needs of populations living in dry lands of the world, and have the potential to provide much more if knowledge on their utilization is expanded. However, their rapid growth and resilience associated with strong competitiveness and invasion of other land systems is causing serious dilemma. The wood is excellent as firewood and charcoal; straight branches are used for fence posts and poles in construction of shelters and homes; sawn timber has a pleasant colour and grain, and shrinks little on drying. Honey produced from the trees, which have long and abundant flowering, is of the highest quality. The exudates gum produced from wounds in the bark is comparable to commercial gum arabic (from *Acacia senegal)* and can be found in large quantities. Leaves are occasionally gathered and used as a mulch or compost on agricultural fields, with some noted fungicidal and insecticidal qualities. The bark is a source of tannins, dyes and fibers, and various plant parts are used in the preparation of medicines, mostly for eye, skin and stomach problems (Pasiecznik et al., 2004). Prosopis pods contain 9-17% protein and 15-37% sugar (Oduol et al., 1986) and crushing improves the feed value of pods, as the protein in the seed will be more available to the animals. Most of the protein content of ripe pods is in the seed, which is said to be comparable to that of soybean (Ibrahim, 1992). However, the small hard seeds pass through the animal digestive tracts largely undigested. This makes prosopis pods to be a better feed only if ground into flour meals. The practice of grinding prosopis pods into flour before feeding animals can also help in reducing the spread of prosopis through animal faeces. Countries like Brazil and South Africa have established a feed mill to grind prosopis pods into flour meals (Richordsen, 1991; Singh et al., 1993). Soil reclamation studies indicated that soil alkalinity up to 10.4 pH can be lowered by prosopis to normal level in 8 years period (Singh et al., 1993). It served as a windbreak by preventing movement of sand-drift and typhoon. There is an indication of reducing air temperature and creating a mild weather. In the Afar region serious water erosion has led to gully formation in areas like Gewane. One of the proposed soil and water conservation activities through out the region is to plant prosopis.

## Perception of the Afar community on prosopis

Although the prosopis problem has elicited mixed reactions by the community

members, there are much more voices requesting an external support to manage the spread or eliminate it altogether and replace it with a better species. Opinion polls indicate that the local people in the Afar region are hostile to prosopis. The hostility comes largely from the undesirable traits of the local population of prosopis plant itself and the lack of knowhow and awareness on the uses and management systems of this plant by the local people (Kassahun et al., 2004). There is still much restriction on its utilization because the region has very small area with vegetation cover and further removal of prosopis will deteriorate the situation (Senayit et al., 2004).

## Prosopis management practices

Hand clearance is the first method used to deal with prosopis on pasturelands. This involved felling of trees, uprooting of stamps and seedlings. It is very expensive and only cost effective on a small-scale application. Another control techniques applied by pastoralists is burning the tree. Charcoal makers associations have been formed and are producing charcoal from the tree. This could help control and prevent the expansion of the tree (Senayit et al., 2004). The government should allocate infested lands to the associations so that their activities would not be haphazard and unplanned.

The control techniques used by commercial farms are clearing using bulldozer, uprooting using human labour and burning prosopis trees found on farmlands, road sides, and irrigation and drainage canals. Commercial farms spend considerable amount of money to control prosopis. Experience of Africa Farm (a different organization from Farm Africa) revealed that the cost of clearing prosopis was birr 16,910 for about 8 ha of land in the year 2001 and birr 9,940 for about 6 ha in 2004 (Senayit et al., 2004). Use of caterpillar tractors that uproot the trees (by chaining) and root ploughing the site is also common. The procedure is effective and long lasting but it is one of the most expensive methods. Chaining is applied by pulling of a heavy chain between two or more slow moving caterpillar tractors. This may be repeated in the opposite direction in order to fully severe the tree roots. This is effective where there are too many large trees (Senayit et al., 2004). Experience elsewhere shows that clearance with a biomass harvester produces wood chips that can be sold for energy production to offset operational costs (Felker et al., 1990). Cutting and pouring used car oil on the cuttings was practiced in the highly infested areas. Hailu et al. (2004) found that stumping trees at 10 cm below the ground eliminates the chance of re-sprouting and this might offer a viable option for controlling and even eliminating the plants from areas where they are undesirable.

## Water Hyacinth (*Eichhornia crassipes*)

Water hyacinth is a perennial, mat-forming, aquatic plant, free-floating or anchored in shallow water, usually 100-200 mm high but up to 1 m when growing in dense mats. The water hyacinth is a monocotyledon of the family Pontederaceae. The plant has funnel shaped and two lipped blue flowers.

In Ethiopia, this weed was officially reported in 1956 in Koka Lake and the Awash River (Stroud 1994). Senayit et al. (2004) also indicated that the earliest observation of water hyacinth in Dugda Bora destrict was reported to be between 1949 and 1958. Sporadic visits, including some clean-up attempts have been made in 1959, 1968, 1979 and 1988 (Stroud, 1994). Before 1958, water hyacinth had never been reported in the Upper Nile Region. By 1962 the plant had succeeded in infesting the whole stretch of the White Nile from Juba to Jebel Aulia Dam; the whole length of the Sobat river from its mouth eastwards up to Baro and Gillo Rivers in Ethiopia and southwards up to Pibo River to Akobo (Rezene, 2005b). The Baro River is the main transportation route between south Sudan and the River port of Gambella. Difficulties experienced by steamers and boats since the advent of water hyacinth have been frequently reported.

## Impact

Water hyacinth poses serious socioeconomic and environmental problems for millions of people in riparian communities and is, therefore, an added constraint on development (Howard and Matindi 2003). The weed obstructs electricity generation, irrigation, navigation, and fishing; increases water loss resulting from evapo-transpiration; increase cost of crop production, provides habitat for vectors of malaria and bilharzias; harbors poisonous snakes; causes skin rashes; and can host agents of amoebic dysentery and typhoid. It prevents oxygenation of water and the establishment of phytoplankton and much of the zooplankton, making areas unsuitable for fish feeding and fish-breeding. Debris from its vegetation and roots create murky water, making it unsuitable for drinking or other domestic uses. These impacts pose an additional burden to the limited health services and facilities available to poor rural communities. However, the water-hyacinth problem is still poorly understood in Ethiopia.

## Distribution

### The Awash River

The point of introduction and the primary source of infestation for the Awash River is assumed to be Aba-Samuel dam that is organically enriched by the Akaki river, which damps almost all types of social wastes of Addis Ababa into

the dam. Farmers in the area reported that foreign inhabitants residing near by the dam introduced water hyacinth to the dam 30-40 years ago.

A survey conducted in the Rift Valley lakes indicated that running water was the most important means of introduction and dissemination of water hyacinth. Among the water sources, the Awash River, Lake Akaki Beseka, Lake Aba Samuel, and Gora River were believed to be some of the most important water bodies that contributed for the introduction and dissemination of water hyacinth in the area (Senayit et al., 2004).

## Rift Valley Lakes

Except Lake Elen (8 km North of Alemtena town), other Rift Valley Lakes: Ziway, Langano, Abiyata, Shala, and Hawassa are proved to be free from water hyacinth, but the risk is still there. The Lake Hawassa was found severely infested by another waterweed species known as water lily (Rezene, 2005b).

## Koka Dam

The Ethiopian Electric Power Corporation (EEPC) reported this weed as a problem disrupting their operation at the three stations located along the Awash River, where it emerges from the Koka Lake (Stroud, 1994). The water intake points become blocked, which must be periodically closed down in order to clean up the weed. EEPC has periodically taken action in the past to remove the weed using human labor. They stopped this method about 15 years ago and the water hyacinth problem has reached to unmanageable proportions once again. EEPC requested experts at various times to make recommendations for control. However, action has not been pursued for one reason or another (Rezene, 2005b).

## Sugar Estates

This weed is a problem of Wonji-Shoa and Metahara Sugar Estates (Firehun and Solomon, 2002). In Wonji-Shoa, it is believed that water hyacinth was first introduced from the Koka hydroelectric power dam because of the 1996 flood of the Awash River in the factory (Tariku, 2001; Firehun et al., 2002; Abera et al., 2004). It is not known when and how the weed was introduced to Metahara, but it is assumed to be intentionally introduced for its ornamental value.

Abera et al. (2004) reported that the weed infested border and central drainage structures, irrigation water reservoirs, and secondary and tertiary irrigation water supplies at Wonji-Shoa. According to Firehun et al. (2006), the weed infested an area of 116.4 ha of water body as opposed to its restricted existence in sewerage canals and water ways located in the residential areas in 1996. At Metahara the distribution of water hyacinth was limited only to about 100 m length drainage canal.

## Gambella area

The Baro River is the main transportation route between south Sudan and the River port of Gambella.

## Perception of the community

Despite the severity of the problem information on the socioeconomic and welfare effects of water-hyacinth infestations is not available. This is certainly an important knowledge gap and a further challenge for researchers (EARO, 2003). Local estimates of economic impacts of water hyacinth in the affected areas of Ethiopian water bodies are unavailable. Further, there is less documented information in this aspect on the impacts of the invasions on water loss, water quality, biological diversity and ecological integrity of the aquatic ecosystem.

It reproduces mainly vegetatively by means of slender horizontal runners called stolons. As the stolon grows, a new plant is formed at its tip and it is a matter of days the parent plant is surrounded by offspring which develop leaves and roots and send stolons by themselves (Rao, 1983).

Holm et al. (1969) reported two parent plants were surrounded by 300 offsprings in 23 days and by 1200 after 4 months. A single inflorescence could have about 20 flowers and each flower produced 3000 to 4000 seeds. The seeds remained viable for over 15 years in the bottom soil. Steamers, boats, canoes, or fishing nets can carry plants upstream. Mats of floating plants may become stranded on banks and shorelines when the water level falls. They float again when the water level rises. Floating plants gather as mats on the leeward side of water. Healthy mats of water hyacinth become a substrate for the secondary growth of papyrus and other similar plants, which makes the mats more solid, heavier, and more difficult to navigate even for large boats (Holm et al., 1969).

## Management practices

Methods to control and contain the weed in the Ethiopian Sugar Estates include manual as well as mechanical clearing and, in some spots, chemical application (Firehun et al., 2006). The Wonji-Shoa Sugar Factory practices mechanical clearing the draining water body to overcome the problem. Special buckets connected to the arm of the vertical cutters which cut a swath through the stand and convey the material to the shore using a centrifugal thrower. Accordingly, the weed is removed from the canals periodically and left to dry at the border of the canals. This practice, however, seems inefficient as the weed reinfests the canals shortly after the practice. Moreover, labourers are reluctant to do the job as the cleaning of the weed from the canals and reservoirs are difficult and tiresome work. Currently, the factory developed short and long-term control

strategies for the different infestation levels, using different control options in an integrated manner (Firehun et al., 2006).

## Other alien and native invasive plant species

Other alien or native invasive species recorded as threats are *Lantana camara*, *Acacia* spp. and the widely distributed genera of parasitic weed species.

### *Lantana camara*

*Lantana camara* (Lantana weed) originally from South America is steadily spreading across Africa. It excludes other species, competes for light, space, water, nutrients, and is poisonous to some herbivores. Lantana weed has usually been deliberately introduced into various localities in Ethiopia (particularly urban areas) as an ornamental shrub, and quickly spread by birds and other animals that eat its fruits. There are also indications that seeds of lantana are water borne as young plants of this species are observed to escape from drainage ditches in the outskirts of Debre Zeit, Nazret, Harar and Dire Dawa. Hot spot areas of lantana are reported to be in eastern Hararghe and neighboring localities of the Somali region forming impenetrable thickets in waste areas, abandoned areas, grasslands and pastures. Lantana quickly takes over valuable grazing lands and its dense growth suppresses grasses and other useful forages. Little else can grow on lantana thickets because the plant releases inhibiting chemicals into the soil to prevent other plants from germinating. The absence of under storey community to provide groundcover resulted in increased erosion, particularly on steep slopes. By excluding other species, the thickets reduce plant biodiversity and change the composition of associated animal communities. Lantana is able to spread rapidly once introduced to an area as the seeds are widely dispersed by birds eating the fruits, and are sometimes also washed from infested areas during floods, causing sudden invasion downstream.

### *Acacia* spp

Native species of *Acacia* such as *A. drepanolobium* and *A. mellifera* are also encroaching on the rangelands of the Borena Zone of Oromia National Regional State, which is known for its endemic cattle breeds in the country and the problem is threatening the biodiversity in rangeland ecosystems as well as the development of livestock production (EARO, 2003).

## Parasitic weeds

Ethiopia is unique for the diversity of its parasitic weed problem. Of about 14 families of higher plants which have parasitic representatives, nine occur in Ethiopia making a varied, colorful and sometimes damaging contribution to the plant life of the country (Parker, 1982). Of these, the species in the families of

Scrophulariaceae (commonly called witch weed or striga), Cuscutaceae (cuscuta or dodders), Orobanchaceae (orobanche or broomrapes), Loranthaceae (*Tapinanthus*) and Viscaceae (*Arceuthobium*, 'dwarf mistletoe' and *Viscum*), represent the most important plant parasitic weeds in agricultural crops and forestry (Parker, 1988).

# Conclusion and recommendation

There is an urgent need to develop and use integrated management for IAS, as it is the case with other weeds. This involves prevention of spread or establishment, manual and mechanical control, use of indirect weed control methods (agronomic practices), biological control, and herbicide use, etc.

## Parthenium

In non-infested crop fields, or in fields where parthenium exists in patches, simple precautions such as field monitoring and sanitation; avoiding movement of vehicles and other machinery, livestock, compost, sand or soil from infested areas to non-infested areas; use of clean crop seeds; control of the isolated outbreaks through spot spray with persistent herbicides or repeated hand weeding or hoeing; and control of parthenium in other habitats like roadsides, wastelands, etc. are mandatory.

For the control of parthenium in fallowland, wasteland, grazing land and roadsides in urban and rural areas, village communities, city councils, agricultural development agencies, and other groups should be organized to manage the weed. Such activity has been started in the northern and central parts of Ethiopia, but lacks continuity and technical operation. Development and enactment of restrictive acts in parthenium weed infested areas after giving good publicity through mass media, seminars, schools and organization of people's participation in uprooting and cleaning of infested areas and application of preventive methods in non-infested areas will reduce the risk of spreading the weed. Maintenance of pastures by avoiding overgrazing and developing vegetation stand in disturbed areas is also mandatory in order to prevent the spread of the weed.

Classical biological control involving the use of insects or pathogens for the control of parthenium, does not easily fit into crop fields. However, it has a great potential in rangelands where the weed has also become a serious problem (Cock and Seier, 1999). Mechanical, cultural and chemical control methods are not feasible under such ecosystem, where the weed covers a large area. Biocontrol seems the only safe, practical, economically feasible, and sustainable method in the end. In this regard, the introduction of already

rigorously tested and promising biocontrol agents from Queensland and Australia can be considered.

## Prosopis Juliflora

The prosopis dilemma is one of the many problems brought about by the introduction of any new species without proper scientific study on its long-term effects on the environment. Experiences from many parts of the world have shown that complete eradication of the established prosopis species is virtually impossible, particularly under the current state of limited knowledge on its management. Meanwhile, one way of going around the prosopis problem is to make use of its huge growing potential by utilizing its products more effectively. Some of the options are:

**Commercialization of *Prosopis* products:** The current trends in the Afar region have shown that trading in prosopis products is a viable undertaking. However, the local district authorities still restrict prosopis product development such as charcoal making and sale of poles. This should be reconsidered because prosopis is a sustainable resource in all respects. However, utilization should be supported only in pre-infested areas in order to prevent further spread.

**Local rules and regulation for intervention:** Commercialization of prosopis products will best be enhanced through formulation of supportive rules and regulation on its utilization. Absence of such a regulation has partly contributed to the uncontrolled spreading of prosopis.

**Land tenure:** Observations and experiences in many parts of the world have shown that prosopis can be much easily controlled under private land tenure system. Ways of privatizing land (as conditions permit) in most of the prosopis affected areas need to be explored as a way of containing prosopis spread.

**Mechanical removal:** Mechanical control of prosopis is not economically viable, except on land of high conservation and bio-diversity value. Mechanical removal of prosopis from important habitats such as national parks, game reserves, riverbanks, irrigation canals may be justified. Communities should also be encouraged to remove young seedlings before they get established on new sites.

**Biological control:** Methods of biological control of prosopis are being tried in other parts of the world (e.g. South Africa) and encouraging results have been reported. Thus, concerned local research institutions should initiate

efforts towards collaborative research with those countries which have already succeeded so that biocontrol agents may be introduced locally to contain the prosopis menace.

### *Eichhornia crassipes*

The establishment and build up of water hyacinth in the Awash River appears to ontinue risking the water bodies in the Rift Valley. Lack of awareness among the concerned bodies to the problem seems to be the most critical barrier to effective action. Therefore, enormous effort is required to address this issue. Such efforts should be backed up by appropriate administrative support, effective institutional arrangements, sufficient human capacity, training, funding, research, education, and legislation. In this context, the following are suggested:

**Prevention measures:** Prevention of further invasions in the down streams of the River Awash is critical. Prevention can include a combination of control measures, legislation, education, communication and commitment.

**Control measures:** Effective control should involve combinations of physical, chemical, biological, and mechanical measures that go along with the environmental approach. In this regard more favor should be given to site specific control systems that integrate the different methods.

Surveys are important prerequisite for planning suitable management strategies for the water hyacinth. Surveys should gear to:

- Identify the problem properly and its source, and the level of infestation, mapping the infested areas as well as categorizing the environments where it is thriving.
- Identify potential new infestations
- Plan and implement continuous and regular monitoring
- Assess existing and potential problems such as socioeconomic problems associated with water hyacinth

**Awareness creation:** The acquisition and flow of information on water hyacinth among those implementing control practices and all concerned should be efficient and supported by modern methods of communication. The urgency of the problem and available control options should be imparted to decision makers and to the community to enable them in making effective and informed decisions for handling the problem. The problem of water hyacinth should be publicised through the media, posters, seminars, etc. in order to awarene and educate the affected communities in the different areas so that they will be efficiently involved in the management programs.

**Collaborative actions:** National programs should build effective institutional frameworks to coordinate activities concerning the water hyacinth problem. Such frameworks should facilitate the participation of major stakeholders (government, NGOs, policy makers, affected communities, and centers of expertise). The interaction of researchers, decision makers, and communities on the issue of water hyacinth management should be improved at national and regional levels.

## Challenges and prospects

The problem of IAS is a major constraint to biodiversity, agriculture as well as animal and human health. Concerted efforts must be made to elaborate control strategies that are efficient and easy to impliment. Combinations of different methods in an ecosystem management approach appear be the best solution to combat these invasive species. To this end the following should be considered:

- Promote new research findings on IAS through appropriate innovative and existing extension networks
- Study the biology and ecology of IAS
- Investigate the impact of IAS on native biodiversity, livestock and human health
- Study the use of competitive desirable plants against IAS invasion
- Study on chemical control of IAS
- Study the merits and utilities of IAS to enhance its management by utilization, including the potential uses such as greenleaf manure, compost, bio-pesticide, soil amendment, fuel wood, etc.
- Search for local and exotic biological agents for the management of IAS
- Develope a participatory approach for the management of the IAS problem
- Establishment of IAS action and research groups both at the Federal and Regional levels that geared to eradicate or contain the IAS problems in urban and rural areas
- Identifying effective information dissemination techniques to create awareness

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# Review of Sugarcane Protection Research in Ethiopia

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## Introduction

Sugar production in Ethiopia has commenced in 1954 at Wonji by the Dutch Company called Handles-Vereening Amsterdam (HVA) with sugarcane plantation of 5,000 ha. Later in 1962, the Company installed the second sugar factory at Shoa expanding the cane plantation by 2000 ha. Similarly, other sugarcane plantations were established at Metahara (> 10,000 ha) and Finchaa (> 8000 ha) in 1969 and 1998, respectively (Getachew, 1987; EARO, 2000; Abera and Tesfaye, 2001).

The sugar industries play a great role in the Ethiopian socio-economy. The country's annual production of sugar from the three sugar estates is about 280,000 tons. Sugar and its by-products are used for local consumption and export. The industry also created job opportunities for more than 25,000 people. The International Sugar Organization (ISO) estimates the present annual consumption of sugar in Ethiopia at 3.5 kg per capita; this is considered low even by African standard, which is about 20 kg per capita (Anon., 2003). According to the report indicated above, to reach to the African standard, Ethiopia still needs to produce an additional 80,000 metric tons of sugar per year to satisfy the current demand for sugar consumption in the country. This implies that much effort has to be made to have reliable supply of sugar in the country. To bridge the gap between supply and demand as well as to exploit the international market, Ethiopia is on the verge of establishing new sugar factories with large tract of sugarcane plantation besides expanding the existing ones. In addition to the aforementioned efforts, intensification of sugarcane cultivation is of paramount importance.

Weeds, diseases and insect pests are among the major constraints of sugarcane production in the country. Various researches have been undertaken in the sugarcane plantations to combat these pests. Thus, this review paper compiles results of sugarcane protection researches undertaken during 1970 to 2005 in the sugar industry of Ethiopia.

# Research findings

## Pests recorded

### Insect pests

Numerous insect pests have been recorded in the sugarcane plantations of Ethiopia to date (Table 1).

Table 1. Insect pests recorded in sugarcane plantations of Ethiopia.

| Scientific name | Common name | Status | Sites | Ref. |
|---|---|---|---|---|
| **Coleoptera** | | | | |
| **Scarabaeidae** | | | | |
| *Heteronychus licas* Klug | Black sugarcane/ maize beetle | Major, but sporadic | W and M | 22 |
| **Homoptera** | | | | |
| **Aphididae** | | | | |
| - | Aphids | Minor | M | 50 |
| **Pseudococcidae** | | | | |
| *Saccharicoccus sacchari* | Sugarcane mealy bug | Minor | W | 49, 50 |
| *Dysmicoccus brevipes* | Pineapple mealybug | Minor | - | 49 |
| **Isoptera** | | | | |
| **Termitidae** | | | | |
| *Macroterms* spp. | Termites | Major | M and F | 50 |
| *Odontoterms* spp. | Termites | Major | M and F | 50 |
| *Pseudacanthtermes militaris* | Sugarcane termite | Major | West Eth. | A |
| **Lepidoptera** | | | | |
| **Crambidae** | | | | |
| *Chilo partellus* Swinhoe | Spotted stalk borer | Major | W, M and F | 49, 50 |
| **Noctuidae** | | | | |
| *Busseola* sp. | Maize stalk borer | Major | W, M and F | 21, 51 |
| *Sesamia nonagriodes* | Sugarcane borers | Major | W, M and F | 21, 49, 51 |
| *S. calamists* | Spotted stalk borer | Major | W, M and F | 21, 51 |
| *Spodoptera* spp. | Armyworms | Occasional | F | 50 |
| **Orthoptera** | | | | |
| **Gryllidae** | | | | |
| *Oecantus pellucens* | Tobacco leaf cricket | Minor | - | 49 |
| Different spp. | Grasshoppers | Minor | - | 50 |
| **Gryllotalpidae** | | | | |
| *Gryllotalpa africana* | African mole cricket | Minor | - | 49 |
| **Acrididae** | | | | |
| *Schistocerca gregaria* | Desert locust | sporadic | W, M and F | 50 |

W = Wonji-Shoa, M = Metahara and F = Fincha; A = Abragham Tadesse, pers. com. - = unknown.

Yoseph et al. (2006a) recently reported some unidentified species of whitefly, leafhopper and leaf miners in Wonji, Metahara and Fincha farms as minor pests. Unidentified trash worm at Fincha and top borer at Wonji were also reported (Tesfaye and Solomon, 2006).

## Assessment of moth borers

Occurrence of moth borers was assessed in fields of Wonji-Shoa sugarcane plantation in 1979. It was reported that shoot and stalk borers were found in some fields of the plantation. The stalk borer was identified in England by the Common Wealth Institute of Entomology as *Sesamia nonagriodes botanephaga* (ARS, 1980). The stalk borer inflicted up to 12% of the damage on sugarcane variety B52298. Higher borer infestation was recorded towards border of the cane fields (ARS, 1980).

## Status of *Eldana saccharina*

A survey was conducted to determine the status of *E. saccharina* on sugarcane and various sedges in and around the commercial sugarcane plantations and sugarcane fields of small-scale farmers in the different parts of Ethiopia. *E. saccharina* was recorded only from sedges of three species (*Cyprus dives*, *C. papyrus* and *C. fastigiatus*) in Wonji-Shoa, Metahara, Lake Awassa, and Lake Tana areas (Yoseph et al., 2006a). The report suggested that although the pest was recorded on wetland sedges of *Cyprus* spp., it could cause damage to sugarcane in the future.

## Weeds

Surveys on weed flora in the sugarcane plantations of Ethiopia were conducted at different periods and locations. The first weed survey was initiated at Wonji-Shoa and Metahara in 1989/90 and at Fincha in 1991/92 (Taye, 1991; Berhanu, 1993). During this period, 143 weed species in 37 families were recorded at Wonji-Shoa and Metahara, and 74 weed species in 21 families at Fincha. In a similar work of 2003/'04 and 2004/'05, 236 weed species were found in the plantations of Wonji-Shoa, Metahara and Fincha (Firehun, 2004; Firehun et al., 2007). These weed species were distributed in 140 genera within 47 families. The large majority of these were dicotyledonous species followed by grasses and sedges (Appendix 1).

The five major families, based on the number of species were: Poaceae, Asteraceae, Fabaceae, Euphorbiaceae and Malavaceae. On the other hand, a similarity index matrix of weed species found in the plantations revealed that all the three crop stages (plant cane, first ratoon and last ratoon), soil types and the three locations have different (<60%) weed communities (Table 2).

Table 2. Percentage similarity index of weed community in sugarcane.

| | Sugar Estates | | | References |
|---|---|---|---|---|
| | **Wonji-Shoa** | **Metahara** | **Fincha** | |
| **Wonji-Shoa** | 100 | 46.54 | 37.53 | 27, 28 |
| **Metahara** | 46.54 | 100 | 41.57 | 27, 28 |
| **Fincha** | 37.53 | 41.57 | 100 | 27, 28 |

## Survey of parasitic weed

According to ARS (1979), assessments of the parasitic weeds (*Striga* spp.) were made by Addis Ababa University at Metahara plains and around Mount Fentale as early as 1969, and the weed was identified to be *Striga latericea* at Kew Botanical Garden, England. About 848 hectares of the plantation were infested by this weed. Similarly, during the survey conducted in 1989/90, *Striga hermonthica* and *Orobache* spp. were recorded at Metahara (Taye, 1991). In addition, the occurrence of *Striga hermonthica* was reported from the Fincha Sugar Estate (ARS, 1980). However, currently the two plantations are reported to be free of any parasitic weed infestation (Firehun and Tamado, 2002; Firehun et al., 2007).

## Assessment of water hyacinth

Water hyacinth is a problem of Wonji-Shoa and Metahara Sugar Estates (Firehun and Solomon, 2002). The weed was introduced to Wonji-Shoa from Koka Hydroelectric Power Dam because of the 1996 flood of the Awash River in the Estate (Tariku, 2001; Abera et al., 2004). In the same report, it was indicated that during 1996, the weed was restricted to drainage structures found in the residential areas. However, currently it covers about 116.4 hectares of irrigation and drainage structures at Wonji-Shoa with infestation levels ranging from low to high (Firehun et. al., 2006a).

## Diseases

Survey of sugarcane diseases were carried out at different times in the sugar estates. According to ARS (20), smut, leaf blotches, and stem rot were reported to be prevalent in some fields of the Fincha sugarcane plantation in 1978. Besides, based on symptoms observed on some fields, the presence of ratoon stunting disease was reported from Metahara in 1979 (ARS, 1980). Similarly, during surveys conducted between 2001 and 2003, 17 diseases were recorded in the sugarcane plantations (Table 3).

Abera (2001b) and Berhanu (1991) reported higher incidence of smut on ratoon crops than that of plantcane at Wonji-Shoa and Metahara.

Table 3. Diseases recorded in sugarcane plantations (after Abera and Teklu, 2005).

| Common name | Scientific name | Status | Site* |
|---|---|---|---|
| Yellow spot | *Mycovellosiella koepki* | Minor | W, M |
| Brown stripe | *Chochliobolus stenospalus* | Minor | W, M,F |
| Brown spot | *Cercospora longipes* | Minor | W, F |
| Purple spot | *Dimeriella sacchari* | Minor | W, F |
| Ring spot | *Leptosphaeria bicolor* | Minor | W, F |
| Leaf scorch | *Leptosphaeria sacchari* | Minor | M |
| Eye spot | *Bipolaris sacchari* | Major | F |
| Red rot | *Glomerella tucumanensis* | Minor | W, M,F |
| Pokkah boeng | *Fusarium moniliforme* | Minor | W, M, F |
| Smut | *Ustilago scitamunea* | Major | W, M, F |
| Pineapple disease | *Ceratocystis paradoxa* | Minor | W, M, F |
| Basal stem and root rot | *Marasmius sacchari* | Minor | W, M |
| Rind/stalk rot | *Phaecytostroma sacchari* | Minor | F |
| Leaf scald | *Xanthomonas albilineans* | Minor | W, M, F |
| Ratoon stunting disease | *Leifsonia xyli subsp. xyli* | Major | W, M, F |
| Red stripe | *Acidovorax avenae subsp. avenae* | Minor | W, M, F |
| Banded chlorosis | Environmental effect | Minor | W |
| Common rust | *Puccinia melanocephala* | Minor | M |

W = Wonji-Shoa, M = Metahara and F = Fincha Sugarcane Plantations.

# Basic studies

## Insect pests

### Biology of black beetle

The black beetle (*Heteronychus licas* Klug) is the most important pest of sugarcane inflicting damage every year to sugarcane plantations at Wonji-Shoa and Metahara (ARS, 1975). Reports indicate that the beetle has one generation per year and it takes one year to complete its life cycle. The female laid eggs more than once and at one oviposition 10-30 eggs were laid. Egg laying continued for extended periods from May to June (Tesfaye, 1991). The eggs when first laid were oval; white objects about 1.7 mm long and 1.5 mm wide. Later, they became more round and greyish and increased in size to one and half or twice their original size. Average incubation period lasted for about 11.5 days and the average percentage of fertility was 98.7(Tesfaye, 1991). The larval stage had three instars that were distinguished by their feeding habits and size. The average period of the first instar lasted for about 35 days and it was feeding on large volume of soil. The second instar was found to feed on fresh roots; and it took 75 days on the average. The third instar was the most important in terms

of crop damage. It was found to feed heavily on sugarcane roots of all age. This instar lasted for about 75 days. Generally, the larval period took about six months on the average.

Pupation began in November and lasted for about 25 days. Adults were shiny black and small beetles when they first emerge from the pupa. But, their size increased and colour changed to dull black as they grow. Average size of adults measured 15 mm long and 8 mm wide. Emergence of adult was found to be associated with soil moisture and began during hot months after the first short rain. In the laboratory, emergence of adults began in January. In the fields of Wonji-Shoa sugarcane plantation damage by adult beetles started in February and continued up to June. As it was indicated by the light trap catches and the level of damage to sugarcane at Wonji-Shoa, adult beetle population reached peak in April (Tesfaye, 1991).

The male and the female are readily distinguished by their size and pro-tarsal claws. Usually the female is larger than the male. Under field conditions, the sex ratio was 1:1 (Tesfaye, 1991). However, a recent study indicated that females were more abundant with a ratio of 1:3 (Solomon, 2005).

It was observed that the black beetle could not survive excess moisture nor dry conditions and exposure to the sun. During the sunshine hour, therefore, they hide up to 30 cm deep in the soil around roots of sugarcane. They are nocturnal in their behaviour and flight and surface activity occurred at night. Feeding and mating were found to occur during the cool hours under moist soil condition. They mate at night and copulation was found to take over 6½ hours (Tesfaye, 1991).

## Susceptible stages of sugarcane to the black beetle

An experiment conducted to assess the most susceptible stage of sugarcane to black beetle at Wonji-Shoa sugarcane plantation indicated that the beetle attacks sugarcane until four month since the time of planting. The most severe damage was recorded when infestations occurred within one to two months after planting (Solomon, 2005). No appreciable tiller loss was recorded when infestation occurred at three to four month after planting.

Sugarcane has the capacity to offset some amount of shoot loss caused by the beetle by producing compensatory tillers. Studies on the compensatory tiller production potential of sugarcane at different ages to different infestation periods of the beetles at Wonji-Shoa indicated that compensatory tiller was sufficient to offset shoot loss when infestation occurred at two and above months after planting (Solomon, 2005).

### Incidence and damage of the black beetle

Field studies to determine the relative incidence and damage of the black beetle did not show a significant difference due to low beetle infestation in the season. However, increasing trend of infestation was observed towards older ratoon crops. The highest crop damage recorded was made on the third ratoon crop and the least was on plant cane fields at Wonji-Shoa. Population of the black beetle showed also strong positive and linear correlation with the extent of damage (Solomon, 2005).

## Weeds

### Determination of critical weed-free period

Crop/ weed competition study made at the Metahara sugarcane plantation for one cropping season showed that sugarcane should be free of weeds during the early growth stage. The critical period of weed competition at Metahara was found to be between 3 to 12 weeks after planting (Taye and Firehun, 2002).

### Effects of weed competition on sugarcane

Studies on the effects of weed competition on vegetative growth and yield of sugarcane at Wonji-Shoa and Metahara sugarcane plantations indicated that there were significant reductions in tiller and stalk population, stalk height and diameters of sugarcane. In addition, weeds were found to cause a yield loss of 42-51% at Wonji-Shoa and Metahara sugarcane plantations. The extent of competition varied with soil types in the study area (Taye, 1991; Taye and Firehun, 2002).

### Weed community analysis

Studies on the effects of some environmental and crop management practices on weed species composition and distribution in the sugarcane plantations indicated that irrigation frequency, crop stages, soil texture, sugarcane variety, rainfall, number of cuttings, weeding frequency in the previous production season and fertilizer application practices influenced the species composition and distribution of weeds (Firehun, 2004; Firehun et al., 2007).

### Weed flora shift

A study made to assess the weed flora shift in sugarcane plantations revealed that there were weed flora shift in the sugarcane plantations (Firehun, 2004; Firehun et al., 2007).

At Wonji-Shoa, *Ipomea cordofana, Ipomea eriocarpa, Corchorus trilocularis, Rhynchosia malacophylla, Galinsoga parviflora, Euphorbia hirta, Euphorbia*

*heteropylla, Pennisetum clandestinum, Xanthium strumarium, Flaveria trinervia* and *Phyllanthus tenellus*; and at Metahara, *Rottboellia cochinchinensis, Ipomea cordofana, Rhynchosia malacophylla, Flaveria trinervia, Euphorbia hirta* and *Euphorbia heteropylla* were the species that gained importance over the last 13 years (Firehun, 2004; Firehun et al., 2007). At Fincha *Muscari neglectum, Hydrocotyle bonariensis, Gomphocarpus fruticosus, Crotalaria deserticola, Crotalaria procera, Chrysanthemum segetum, Calendula arvensis* and *Amaranthus reteroflexus* have become important over the last decade (Firehun et al., 2007).

# Diseases

## Yield losses in sugarcane due to smut

Four major sugarcane varieties with distinct reaction to smut were used for yield loss studies at Metahara using four levels of spore concentrations ($5 \times 10^3$, $5 \times 10^4$, $5 \times 10^5$ and $5 \times 10^6$ spores/ml). The overall effects of systemic infection by smut on sugarcane plants were the reduction in the quantity of millable stalks, cane and sugar yields. In this study, 11.78 to 33.03%; 19.43 to 43.06% and 29.48 to 42.81% losses of millable stalk, cane and sugar yields, respectively, were recorded (Abera and Mengistu, 1992).

## Characterization of *Ustilago scitaminea* isolates

Six isolates of *Ustilago scitaminea* were collected from different sugarcane varieties at Metahara and Wonji-Shoa Sugar Estates. Spore morphology, cultural characteristics and morphology of the germinated spores of each isolate were assessed. The level of virulence of the isolates was also evaluated on five sugarcane varieties in the greenhouse. Results indicated that the isolates were similar in spore wall marking (punctate), spore colour (light brown), spore shape (spherical), and spore size (6.46-7.22 μm), except one isolate which was significantly different in spore size. The isolates were similar in colony colour. Morphological characteristics of germinated spores also revealed that the isolates were similar in colour (hyaline), length (18.58 to 20.68 μm) and width (3.24 to 3.72 μm) of promyclium. Moreover, the length (4.68 to 5.98 μm), width (1.57 to 1.69 μm), shape (oval) and colour (hyaline) of sporidium of the isolates were similar.

Regarding comparative virulence of the isolates, each variety exhibited similar reaction to all of the isolates used for virulence test. Therefore, based on results of these studies, no physiological races of the smut fungus seemed to occur in sugarcane plantations of Metahara and Wonji-Shoa (Abera, 1991).

# Pest management methods

## Chemical control

### Insecticide screening against the black beetle

Insecticide screening trials were conducted in the sugar estates at different periods. The efficacies of Benzene hexa-chloride (BHC) at three rates and Aldrin at two rates were evaluated against the black beetle in pot experiments at Wonji-Shoa and Metahara in 1973/74. The results showed that BHC at 2 kg/ha and Aldrin at 4 kg/ha killed 65% and 75% of the 20 beetles placed in each pot, respectively. BHC at 2 kg/ha was recommended for the control of the pest (ARS, 1975). Similarly, another insecticide trial was initiated at Metahara in 1993/94 following the banning of the chlorinated hydrocarbons. Six insecticides at three rates including Lindane as a standard check were evaluated. The highest percentage pest control was obtained with Suscon Green 10 G at 30 kg/ha, Basudin 600 EW and 600 EC each at 3 l/ha. Based upon the cost-benefit ratio, Basudin 600 EW and Basudin 600 EC each at 3 l/ha were recommended to be the best among the test insecticides (Abera, 2001d). Ethiozinon 60 EC (3 l/ha) was also recommended at Metahara (Tesfaye, 2004a).

### Method of insecticide application

In the Metahara sugarcane plantation, insecticide is applied at planting, whereas herbicide application is done at the time of second irrigation. These independent applications of insecticide and herbicides increased the cost of production. Therefore, mixed application of insecticide (Lindane) with herbicide was compared with separate applications of each pesticide. Results showed that the two methods of insecticide application did not show significant difference in pest control on all the test varieties (Abera, 1996).

### Insecticide screening against termites

Seven new insecticides with three rates each and the standard check (Dursban 48% EC) was tested on plantcane and ratoon crops independently during the 2000 and 2003 seasons. Accordingly, Actara 25 WG (900 g/ha), Basudin 600 EW (4.5 l/ha), Ethiozinon 60% EC (4.5 l/ha), Confidor 200 SL (0.75 l/ha), Regent 500 SF (0.25 l/ha), Pyrinex 48% EC (3 l/ha), and Talstar 100 EC (2 l/ha) showed significant control of the pest though they were statistically at par with Dursban 48% EC at 3 l/ha both in plantcane and ratoon crops (Tesfaye, 2004b).

## Herbicide screening

In a trial carried out in 1970/71 at Wonji-Shoa with different herbicide mixtures it was found that a mixture of Sodium trichloroacetate (NaTCA) at 4.75 kg/ha and 2, 4-D Amine (4 l/ha) was effective in percentage weed control and it was safe to the crop as compared to Dalapon (6.8 and 7.2 l/ha) and Dalapon (2.16, 3.6, 4 and 5 l/ha) mixed with 2, 4-D Amine (4, 5, 6.8, 7.2 and 13.6 l/ha) applied as pre- and post-emergence herbicide, respectively (ARS, 1971). It was reported that Gesapax 80% WP (3 and 4 kg/ha) mixed with 2, 4-D Amine (5 l/ha) and Gesapax H 500 EC (6 and 8 kg/ha) showed satisfactory control of broad-leaved and grass weeds including *Cyperus rotundus* as compared to the standard herbicide, NaTCA combined with 2, 4-D amine during the 1971/72 cropping season at Metahara (ARS, 1972). In 1973/74 trial at Wonji-Shoa, Gesapax 80% WP (3 kg/ha) mixed with 2, 4- D Amine (2.5 l/ha) and Sencor (2 l/ha) mixed with 2, 4 – D Amine (5 l/ha) showed significant weed control potential as compared to Gesapax Combi 80% WP (3 l/ha) combined with 2, 4-D Amine (5.5 l/ha), Banuel (1.2 kg/ha) combined with Probe (3 kg/ha) and NaTCA (5 kg/ha) mixed with 2, 4-D Amine (5.5 l/ha) (ARS, 1974). In a similar study at Metahara (1977/78), it was reported that combined mixture of Acetanilide 500 EC (6 and 8 l/ha), Gesapax 500 FW (4 kg/ha) and 2, 4-D Amine (1.5 l/ha) showed effective control against grasses and *Cyperus* spp. The mixture of Ametryne 80% WP (3 and 5 kg/ha) with 2, 4 – D Amine (3 and 5 l/ha) and Diuron 80% WP (4 kg/ha) with 2, 4-D Amine (4 l/ha) were found to be effective against broad-leaved as well as grass weeds (ARS, 1978).

It was reported that an intermittent direct foliar application of Ametryne 80% WP (6 kg/ha) combined with 2, 4-D Amine (6 l/ha) effective in controlling striga when applied every fortnightly for about three months (ARS, 1979). In 1989, six herbicides namely, 2,4-D Amine (2 and 4 l/ha), Gesapax Combi (6 and 8 l/ha), Sencor (1 and 2 kg/ha), Sencor Combi (3 and 5 kg/ha), Dimepax (6 and 8 l/ha) and mixture of Gesapax Combi and 2,4-D Amine (6 + 1.5 l/ha and 8 + 2 l/ha) were evaluated on sugarcane plantations in two soil types at Wonji-Shoa and Metahara (Taye, 1991; Abera, 2001e). The effectiveness of the herbicides against total weed density (broad-leaved + grasses + sedges) was satisfactory except Sencor (1 kg/ha) in sandy soil of Wonji-Shoa and 2, 4-D (2 l/ha) in sandy loam soil of Metahara. In both estates, the least effective herbicide on the two soil types was 2, 4-D at 2 l/ha (Taye, 1991; Abera, 2001e). Burning symptom on the margins and top of the lowermost leaves was reported which disappeared within two weeks after spray as the affected leaves recovered. And none of these symptoms was reflected on the yield and yield components considered. Among these herbicides, Gesapax Combi (ametryne + atrazine) 500 FW was registered for sugarcane weed control in Ethiopia. In 1993 to 1995, the performance of 3 pre-planting, 15 pre-emergence and 18

post-emergence herbicides were evaluated on luvi and vertisols of Fincha (Girma, 1995a; 1996).

From the non-selective pre-planting trial, it was reported that Paraquat and Basta caused a rapid scorching and burning of leaves of weeds within few days of spray. However, their efficacy lasted only for two weeks after spray (Girma, 1995a). Moreover, the effect of Paraquat and Basta was restricted to grass and some broad-leaved weeds; they were poor against sedges. On the other hand, Glyphosate controlled all weed groups, and its control effect lasted longer. Among the pre-emergence herbicides, a mixture of Velpar and Diuron at 0.8 + 3 kg/ha, Velpar at 1 kg/ha, Atramet Combi at 8 l/ha, Gesapax Combi at 8 l/ha, Gesaprim Combi at 5 l/ha, Gesapax at 8 l/ha were effective in both soil management groups at Fincha. Velpar showed significantly effective control of sedges than the other herbicides (Girma, 1996). On the other hand, a mixture of Velpar and Diuron at 0.8 + 3 kg/ha, Velpar at 1 kg/ha, Atramet Combi at 8 l/ha, Sancopax at 8 l/ha and Gesapax Combi at 8 l/ha were found to be the most effective. However, application of Velpar as post-emergence herbicide was found to be phytotoxic to the cane. The use of Velpar as pre-emergence herbicide is restricted only to ratoon crops due to its phytotoxicity effect on plantcane. Atramet Combi (ametryne + atrazine) 50 SC and Velpar (hexazinone) 75 DF were registered pre-emergence herbicides for weed control in sugarcane in Ethiopia.

Moreover, 14 herbicides (7 pre- and 7 post-emergence) were evaluated each at three rates at the three sugarcane plantations between 2001/02 and 2004/05. The results indicated that Primagram Gold at 4 and 6 l/ha to be the most effective and safe pre-emergence herbicide at all locations. Primagram Gold at 4 and 6, Authority at 1 and 1.5 kg/ha, kirsmat at 1.5 and 2 kg/ha were the most effective and safe post-emergence herbicides. Aterbutex at 9 l/ha was also effective and a safe post-emergence herbicide at Fincha (Firehun and Solomon, 2005).

Atramet Combi was compared with the standard herbicide (Gesapax Combi) at Wonji and it was found that both herbicides were similar in their weed control potential and safety to the crop (Firehun and Teklu, 2003).

Similarly, Atramet Combi alone and mixed with 2 4-D were compared with standard herbicide (Velpar) on ratoon crops at Fincha. Velpar at 0.8 kg/ha was found to be more effective than Atramet Combi at 7 l/ha in Luvisols fields (Firehun et al., 2005). In Vertisols fields, Velpar at 0.85 kg/ha was significantly more effective than Atramet Combi at 8 l/ha. In both soil management groups, Velpar showed better control of broad leaf and grass weeds; whereas Atramet

Combi was better in controlling sedges. On the other hand, combination of Atramet Combi and 2,4-D (7 + 2.5 l/ha) showed significant total mean weed control in Vertisols than the other post-emergence herbicides at 6 + 3 l/ha, while in Luvisols both rates (6 + 3 and 7 + 2.5 l/ha) showed better total weed control (Firehun et al., 2005).

### Fungicide screening against sugarcane smut

Disinfection of sugarcane planting materials using fungicides and/or hot water has been the major approach to control the smut disease in sugarcane plantions. However, because of practical limitations the use of hot water treatment is restricted to primary nursery (initial seed-cane nursery). Fungicides have been used to treat planting materials for large scale planting since long ago.

Five fungicides, Tilt 25% EC (0.5, 1 and 1.5 ml/lit), Bayfidan 25% WP (0.5, 1 and 1.5 g/l), Bayleton 25% EC (0.5, 1 and 1.5 ml/l), Vincit 50% WP (1, 2 and 3 g/l), and Benlate 50% WP (0.25, 0.5 and 0.75 g/l), Agallol 6% Hg (standard) at 2.5 g/l of water were tested each at three rates. Each fungicide at all rates reduced smut incidence as compared to the untreated control; Tilt, Bayfidan, Bayleton and Vincit reduced smut incidence by 90.82 to 95.6, 79.4 to 90.7%, 85.6 to 92.9% and 92.7 to 94.0%, respectively (Abera, 2000). The fungicides improved sett germination as compared to the control. The test fungicides were not significantly different from each other ($P \leq 0.05$) in millable stalks and cane yield. But in sugar yield, Vincit at 1 g/l was significant ($P \leq 0.05$) different from Bayfidan at 1 and 1.5 gm/l, and Bayleton at 1.25 and 3.75 ml/l. The cost-benefit ratio of the test fungicides ranged from 1:1.9 to 1:1.9.

### Use of cane knife disinfectant

Sanitation of cane knife with chemical disinfectants is important in preventing healthy cane from infection by the bacterium, particularly the ratoon stunting disease (*Leifsonia xyli subsp. xyli).* The chemical disinfectants that have been recommended for cane knives in the sugar estates are Lysol (Cresylic acid) at 120 ml/l, Ethanol 99.8% at 1 l/ l and Dettol at 10 ml/l of water. To assure disinfection the knife should be kept in the solution for at least five minutes after chopping every stalk into pieces (Abera Tafesse, 2006, personal observation).

## Cultural control

### Effect of planting date on black beetle damage

The effect of planting dates on black beetle damage was studied on two sugarcane varieties at Wonji (Tesfaye, 1991). Significant shoot damage was recorded on sugarcane planted from March 15 onwards in fields with light and

heavy soils. Shoot damage was not significant on sugarcane planted on January 15 and February 15 in both soil types.

The highest significant percentage recovery of shoots in heavy soils was recorded for planting dates from March 15 onwards. In light soils, however, the percentage recovery didn't vary significantly for all planting dates.

Planting on February 15 gave significantly the highest tiller population in heavy soils. The least tiller number was recorded for March 15 and April 15 plantings. In light soils, the difference in the number of tillers was not significant except for April 15 planting which gave the least number of tillers. In heavy soils, millable stalks and cane yields were significant for January 15 and February 15 plantings. In another study at Metahara, similar findings have been reported (Abera, 2001c). January 15 and February 15 plantings significantly reduced beetle damage. Increasing trends in the percentage dead-shoots were observed in plantings from March 15 onwards. Early plantings have also increased the number of tillers and stalks of sugarcane.

## Effect of mulching on weed control

Sugarcane produces large tons of trash per hectare. This trash if used as a trash blanket following green cane harvest gives several advantages. In this regard, a study on feasibility of cane trash mulching after harvest was conducted at Fincha Sugar Project. The trial was conducted for one cropping season by comparing results of cane trash burned and trash mulched after green cane harvest. The result indicated that there was no significant difference between the two treatments in the number of stalks, cane height and cane weight per stalk (Girma, 1995b). However, sugarcane plants on the mulched plots had closed canopy one month earlier than the burned plots. It was also found that sugarcane trash mulching following harvesting of green cane effectively suppressed weed infestation by 91.7 to 100%, including noxious weeds (Girma, 1995b). Moreover, in both treatments no insect pest and disease incidences were observed during the study period but mechanical inter-row cultivation and fertilization practices were affected by the mulch.

## Rouging of smut affected stools or shoots

Rouging of smut affected stools or shoots have been widely recommended as a means of reducing smut inoculum in the field. The sugar estates practice rouging of smut affected stools at 10 and 15 days interval from about two months until the crop reaches inaccessible height both in the nurseries and commercial cane fields, respectively (ARS, 1980).

# Host plant resistance

## Reaction of sugarcane varieties to black beetle

Resistance of different sugarcane varieties have been evaluated at Wonji-Shoa sugarcane plantation (Tesfaye, 1991). The least significant shoot damage was recorded from variety B52298. Tiller population and cane yields were significantly lower in variety NCO310. Although B41227 showed significant shoot damage, tiller population and cane yields were statistically at par with B52298.

## Reaction of sugarcane varieties to smut

Efforts have been made to screen sugarcane varieties for resistance to smut diseases. Results of variety screening trials conducted during 1970 to 1998 indicated that 217 varieties fell within the range of very highly resistant to moderately resistant, whereas 44 varieties were in the moderately susceptible to very highly susceptible categories (Table 4). Varieties in the category of susceptible to very highly susceptible had smut whip emerged relatively earlier (about two months after planting), while in the resistant ones it was delayed by three months after planting. In most varieties, large numbers of whips was observed between 3-5½ months after planting (Abera, 1995).

# Physical methods

Hot water treatment cures setts from the smut disease, if proper combination of temperature and time are used. The Sugar Estates have been practising 50$^{o}$C for 2 hrs. However, this temperature and time combination was reported to adversely affect bud survival. To overcome this problem a trial was conducted to search for the best temperature and time combination at Wonji-Shoa and Metahara. Four temperature levels (ambient, 50, 52 and 54$^{o}$C) and six exposure periods (20, 40, 60, 80, 100 and 120 min) were evaluated using smut susceptible varieties. It was observed that over 90% smut disease control was achieved with canes exposed to 50$^{o}$C for 100-120 min, 52$^{o}$C for 60-120 min, 54$^{o}$C for 40-120 min. at both locations. Statistical analysis, however, showed that reductions of the disease incidence at the exposure periods of 80-120 min., 40-120 min, and 20-120 min., at the respective temperatures of 50, 52 and 54$^{o}$C were not significantly different ($P \leq 0.05$) at both locations.

Table 4. Reaction of sugarcane varieties to smut (*Ustilago scitaminea).*

| Sugarcane varieties and their smut reaction grouping | | |
|---|---|---|
| **Very highly resistant to moderately resistant** | **Intermediate** | **Very highly susceptible to susceptible** |
| B57-36, B58-230, B35-269, B52-107,B53-164,B44-25, B50-210, B54-90, CO740, CO810, CO967, CP52-68, CP69-1059, CP72-2083, CP71/396, D141/46, DB377/60, Mex54/245, PR1007 B52-298, B49-388, B60,163, CO467, CO842, CO620-82, Mex57/197, S17, B41-227, B39-250, B63-349, B52-158, CO449, CO1001, CO680, CO684, CO678, CP36/111, CP71-400, CP61-37, PR1013 DB414-66, B47-386, B49-386, B49-06, B49-224, B51-410, B54-142, B57-141, B57-150, B58-230, B59-212, B60/63, B60-349, B52-158, BO3, B59-212, B51-321, B41-211, B61-13M B35-269, B52-313, CO464, CO718, CO758, CO911, CO957, CO967, CO1007, CO1230, CO798, CO434, CO997, CO961, CO945, CP63/111, CP47/193, CP70/321, CP69/1059, CP61/39, CP71/400, CP71/421, CP71/396, CP53/18, CB38/39, DB414/66, H53/263, L60/40, M202/46, M377/5, Mex57/197, N6, N53/219, N53/216, PR1013, M202/48,N52/219, CP52/68, Mex52/29, B51-129, CB56/20, CO785, CO1148, CO1158, CO1190, CO1202, CO1208, CO62081, CO62175, CP63/588, CP70/330, N11, B37-172, B40-98, B41-22, B42-231, B43-62, B45-151, B47-44, B47-419, B49-119, H49/3633, H39/5803, H39/7028, H44/6364, H44/3098, H46/2404, H48/4605, H49/5, H50/7209, H51/168, Hybrid K5, M31/45, M112/34, M134/32, M147/44, M253/48, M442/41, M442/51, Mex53/142, Mex54/255, N7, N50/93, N50/123, N50/211, N51/168, NCO339, CO421, M168/38, NCO310, CO677, CO740, CO746, CO775, CO976, CO991, CO1186, COK30, COS245, COS443, COS510, CP29/116, CP29/291, CP36/105, CP44/101, CP48/103, CP60/23, DB95/57, D188/56, DB228/57, DB377/60, DB414/60, Ebene 1/37, F134, F141, H32/8560, H37/1983, H38, 2915, H38/4443, B51-116, B51-131, B51-132, B51-415, B53-64, B53-164, B54-90, B57-36, B57-08, B60-125, BO10, BO11, BO29, CB36/14, CB38/22, CB40/69, CB45/3, CB147/15, CB49/260, CO245, CO331, CO440, CO453, CO475, CO513, CO602, CO617, CO622, CO644, NCO349, NCO376, NCO382, P52-337, PPQK1604, PJNDAR, POJ2878, PR905, PR980, PR1000, PR1007, PR1059, Q50, Q57, Q66, Q67, Q70, TORJAN, WO-I, WO-II, Yellow cane, NCO334 | B51-116, CO1007, CO1186, CP60-23, CP61/39, CP70-321 | B46-81, B51-410, B54-142, B4906, B49-224, B59-212, B60-267,B6113, B57/150, B60-191,B52-349, B51-131, B41-211, CO976, CO945, CO434, CO718, CO602, CO1230, CO779, CO961, CP53/18, CP41-76, D42/58, DB18/56, DB22857,Mex52/29, Mex53/142, NCO334, NCO376, N6, N14, N51-168, F134, F141, PR1059, CO421, B31-72, B39-250, B39-254, B57-133, B59-104, B61-09, B62-347, BO14, CB40/35, CO419, CO467, CO765, CO853, CO953, CO1157, CO1198, CO62105, CP65/357, CP68/1026, CP68/1067, CP71/441, CP71/443, CP71/341, H44/2364, H55/783, L60/14, Mex57/473, Mex59/1828, N8, N14, N55/805 |

Sources: Abera 1996 and 2001a.

Regarding sett germination there was no significant difference ($P \leq 0.05$) among the exposure periods of 20 to 80 min, 20 to 60 min and 20 to 40 min. at 50, 52 and 54$^{o}$C, respectively, at both locations. On the other hand, sett germination was relatively improved over the standard check when they were treated for 20 min in hot water at 50 and 52$^{o}$C. At these temperature and time combinations, however, the disease incidence was relatively high. It was observed that better cane yield was recorded at the low exposure time at each temperature. Nevertheless, there was no significant difference ($P \leq 0.05$) within the same treatment category except at 54$^{o}$C for 100 and 120 min. The possible reason for the low cane yield at each temperature as the exposure time increased could be the negative effect of the treatment on sett germination. The occurrence of high smut incidence at the low exposure period could be accountable for the low cane yield.

However, though hot water treatment controlled the smut disease, it has a deleterious effect on yield particularly at high temperatures and longer exposure periods. In general, the best combination of hot water temperature and exposure time for minimizing smut incidence, and relatively less negative effect on sett germination could be 50$^{o}$C for 80 min, 52$^{o}$C for 40 min and 54$^{o}$C for 20 min (Abera, 2005). Nevertheless, these temperature and time combinations may not be effective against other sett-borne diseases.

## Biological control

Assessment of potential pathogens found in association with water hyacinth was made at Wonji-Shoa Sugar Factory. The fungal pathogen *Epicoccum* sp., *Myrothecium verrucaria* (Alb. and Schwein.) Ditmar, *Glomerella cingulata* and *Fusrarium equsiti* (Corda) Sacc were found in association with the weed. Some of these fungi can be used as biocontrol agents for the management of the weed as reported by the Commonwealth Agricultural Bureau International, United Kingdom (RTSD, 2005). Among these fungal pathogens, pathogencity test of *Fusrarium equsiti* (Corda) Sacc confirmed that it has a significant potential for the control of the weed (Firehun et al., 2006b).

Similarly, assessment of natural enemies found in association with borers was made in commercial and small-scale sugarcane fields and wild hosts during 2003 to 2004. Different species of insect parasitoids and pathogens were recorded (Yoseph et al., 2006a; 2006b). List of the natural enemies of borers recorded in the country is indicated in Table 5.

Table 5. Natural enemies, pest stage attacked and level of parasitism/infectivity.

| Natural enemy | Category | Host insect and stage affected | Parasitism/ Infectivity (%) | Ref. |
|---|---|---|---|---|
| **Diptera**<br>**Tachinidae**<br>***Schembria eldanae***<br>Barraclough | Insect parasitoid | Larva of<br>*Eldana saccharina* | 5.26 | 50 |
| *Actia* sp. | Insect parasitoid | Larva of<br>*E. saccharina* | 6.33 | 50 |
| *Linnaemya* sp. | Insect parasitoid | Pupa of<br>*Busseola* sp. | 6.3 | 51 |
| **Hymenoptera**<br>**Braconidae**<br>*Cotesia sesamiae*<br>Cameron | Insect parasitoid | Larva of<br>*Busseola* sp. | 4.7 | 51 |
| *C. flavipes* Cameron | Insect parasitoid | Larva of<br>*S. calamistis* | 2.3 | 51 |
| **Eubacteriales**<br>**Bacilliaceae**<br>*Bacillus thuringiensis*<br>Berliner | Bacterial pathogen | Larvae of<br>*E. saccharina*<br>*S. calamistis*<br>*Busseola* sp. | 10.13<br>34.9<br>34.9 | 50<br>51<br>51 |
| **Entomophthorales**<br>**Entomophthoraceae**<br>*Entomophthora* sp. | Fungal pathogen | Larvae of<br>*E. saccharina*<br>*Busseola* sp. | 5.26<br>2.3 | 50<br>51 |
| **Deuteromycoyina**<br>**Hyphomycetes**<br>*Beauveria bassiana*<br>Balls | Fungal pathogen | Larva of<br>*Busseola* sp. | 6.3 | 50 |

# Conclusion and recommendations

Since the inception of crop protection research in the sugar industry some 35 years ago, a number of research activities were undertaken. Some of them can be applied directly, while some others need further verification. From the findings to date the following recommendations could be made:

- Tilt, Bayfidan, Bayleton, and Vincit at 1ml, 1g, 1 ml and 1g/l, respectively, could be used for treatment of sugarcane planting materials against smut disease.
- Rouging of smut-affected shoots/stools should be made between 1.5 to 8 months of crop age at 10 days interval for nursery and 15 days interval for commercial cane fields.

- Those varieties whose smut reaction ranked from very highly resistant to moderately resistant could be used without fungicide treatments against smut.
- Lysol (Cresylic acid) at 120 ml/l, Ethanol 99.8 % at 1 l/ l and Dettol at 10 ml/l of water could be used for cane knife disinfection to control the ratoon stunting disease.
- Among the herbicides tested, Gesapax Combi/Atramet Combi (6 and 8 l/ha), Velpar (0.8 and 0.85 kg/ha), and Primagram Gold (4 and 6 l/ha), could be used as pre-emergence herbicide for sugarcane weed management.
- Use of Velpar as a pre-emergence herbicide should be restricted only to ratoon cane fields.
- Gesapax Combi/Atramet Combi (6 and 8 l/ha), 2,4–D (3 l/ha) in combination with Gesapax Combi/Atramet Combi (6 and 8 l/ha), Primagram Gold (4 and 6 l/ha), Kirsmat (1.5 and 2 kg/ha), Authority (1 and 1.5 kg/ha), and Aterbutex (9 l/ha) can be used as post-emergence herbicide in sugarcane.
- Early season planting (January to February) on heavy soils could provide successful escape of the black beetle infestation.
- Among the insecticides, Suscon Green 10G (30 kg/ha), Basudin 600 EW, Basudin 600 EC and Ethiozinon 60% EC each at 3 l/ha could be used for black beetle control.
- Insecticide application against the black beetle should not be made if the crop is more than two month old
- Actara 25 WG (900 gm/ha), Basudin 600 EW (4.5 l/ha), Ethiozinon 60% EC (4.5 l/ha), Confidor 200 SL (0.75 l/ha), Regent 500 SF (0.25), Pyrinex 48% EC (3 l/ha), and Talstar 100 EC (2 l/ha) could be used for the control of termites in sugarcane fields.

## Gaps and challenges

The Research and Training Services of the Ethiopian Sugar Industry Support Center nationally undertakes research for the sugar sub-sector. The Crop Protection Department has limited research facilities and skilled manpower to fulfil the increasing research demand of the sub-sector. Smut, ratoon stunting disease, eye spot, black beetle, termites, bind weeds, itch grass, sedges and water hyacinth are also challenges of the sugar estates. Besides, the following points are some of the research gaps to be filled.

- Investigating appropriate hot water temperature and exposure time which cures the setts from all-important sett-borne diseases but with minimum bud damage

- Verifying use of trash mulch for weed control on large scale in a multidisciplinary approach
- Verifying results of herbicides, insecticides and fungicides on large scale
- Lack of breeding facilities in order to utilize the genetic potential of some resistant varieties against the major pest

## Prospects

In order to satisfy the ever-increasing demand of sugar in the country as well as to exploit the international market for sugar and its by-products, the government of Ethiopia has given due attention to expand the sugar sub-sector. Thus, to meet the objectives of the nation, the Crop Protection Department should be strengthened with research facilities and skilled manpower. Some of the future crop protection research in the sugar sub-sector should include the following:

- Periodical surveys of diseases, insect pests and weeds in the existing and forthcoming sugarcane plantations
- Determine yield loss, economic threshold levels and control measures for the major sugarcane pests
- Screen effective pesticides for the control of pests in the new sites as well as existing sugarcane plantations
- Conduct integrated pest management studies especially to utilize cultural practices with minimum pesticide use
- Develop and implement strong quarantine services
- Devise better weed control strategies for each estate taking into account differences in soil types and crop varieties
- Quick detection and swift action to contain or eradicate newly emerging pests at each estate
- Special emphasis has to be given for the management of the most abundant and troublesome weed species such as *Cyperus spp.*, *Rottboellia* spp., *Ipomea* spp. and *Snowdenia polystachya*
- Attention has to be given to crop management practices *in-situ* (e.g. tillage, gap filling) that successfully reduces the abundance and/or dominance of weed species in a given site
- Due attention should be given to the management of aquatic weeds

Appendix 1. Weed species recorded in the different sugarcane plantations.

| Family and botanical name | Common name | Site | Status | Ref. |
|---|---|---|---|---|
| **Acanthaceae** | | | | |
| *Asystasia* spp | | W | Minor | 31 |
| **Agaricaceae** | | | | |
| *Agaricus bisporus* (J. Lange) Imbach | Mushroom (E) | F | Minor | 31 |
| **Aizoaceae** | | | | |
| *Trianthema portulacastrum* L. | Auwud-fwilla (T) | M | Minor | 31 |
| *Trianthema triquetra* Willd. | | M | Minor | 31 |
| *Zaleya pentandra* (L.) Jeffery. | Gurre (T) | MF | Minor | 28,31 |
| **Amaranthaceae** | | | | |
| *Alternathera pungens* (L.) R.Br. (E) | Devil's horse whip | MWF | Minor | 28, 31 |
| *Alternathera sessile* | | F | Minor | 28 |
| *Amaranthus dubius* Thell. | Pig weed | MW | Minor | 31 |
| *Amaranthus graecizans* L. (E) | Spreading pig weed | MWF | Minor | 28, 31 |
| *Amaranthus hybridus* L. | Smooth pig weed (E) | MWF | Major | 28, 31 |
| *Amaranthus retroflexes* | | F | Major | 28 |
| *Amaranthus spinosus* L. | Spine pig weed (E) | MW | Minor | 31 |
| *Celosia trigyna* L. | Belibila (A) | MWF | Major | 28,31 |
| **Amaryllidaceae** | | | | |
| *Nothoscordum inodorum* | | F | Minor | 28 |
| **Apiaceae** | | | | |
| *Oxalis corniculata* L. | Oxalis (E) | WF | Minor | 28,31 |
| *Oxalis debilis kunth* | | W | Minor | 31 |
| *Oxalis latifolia* H.B.K. | | WF | Minor | 28,31 |
| **Araceae** | | | | |
| *Colocasia esculentus* | | F | Minor | 28 |
| **Asclepeidaceae** | | | | |
| *Calotropis procera* (Ait.)f. | Thobua (A) | M | Minor | 31 |
| *Gomphocarpus fruticosus* (L.) Ait. f. | | MWF | Major | 28,31 |
| **Boraginaceae** | | | | |
| *Cordia monoica* Roxb | | M | Minor | 31 |
| *Cynoglossum lanceolatum* Forsk. | Krecha (A) | MWF | Minor | 28,31 |
| *Heliotropium cinrascens* D.C. | Amangemel (T) | MWF | Minor | 28,31 |
| *Trichodesma zeylanicum* (L.) R. Br. | Late weed (E) | MF | Minor | 28, 31 |
| **Brassicaceae** | | | | |
| *Brassica oleraceae* | | F | Minor | 28 |
| **Caesalpiniaceae** | | | | |
| *Caesalpinia decapetala* (Roth) Alston | Mauritius thorn (E) | W | Minor | 31 |
| **Capparidaceae** | | | | |
| *Cleome brachycarpa* Vahl. Ex Dc. | | M | Minor | 31 |
| *Cleome monophylla* L. | Spindle pod (E) | MWF | Minor | 28, 31 |
| *Cleome cilliata* | | F | Minor | 28 |
| *Cleome viscosa* L. | | W | Minor | 31 |
| *Gynandropsis gynandra* (L.) Briq. | Spider flower (E) | M | Minor | 31 |

Appendix 1. Contd.

| Family and botanical name | Common name | Site | Status | Ref. |
|---|---|---|---|---|
| **Caryophyllaceae** | | | | |
| *Corrigiola capensis* Willd. | Kechkech (A) | M | Minor | 31 |
| *Stellaria media* (L.) Vill. | Chick weed (E) | W | Minor | 31 |
| **Chenopodiaceae** | | | | |
| *Centrosoma pubsense* | | WF | Minor | 28,31 |
| *Chenopodium album* L. | Common lambsquarter (E) | MWF | Minor | 28,31 |
| *Chenopodium fasciculosum* Allen. | | M | Minor | 31 |
| *Chenopodium opulifolium* Koch | Hamli-Kubo (T) | W | Minor | 31 |
| *Chenopodium procerum* (Hochst ex.) Moq. | Amedimado (A) | MW | Minor | 31 |
| **Cruciferae** | | | | |
| *Erucastrum arabicum* Fisch. and May. | Gomen-wer (A) | MW | Minor | 31 |
| *Rapistrum rugosum* (L.) All. | | WF | Minor | 28, 31 |
| **Cyperaceae** | | | | |
| *Cyperus assimilis* Steud.(E) | Yellow nutsedge | MFW | Minor | 28, 31 |
| *Cyperus esculentus* L. | Purple nutsedge (E) | MWF | Minor | 28, 31 |
| *Cyperus rotundus* L. | | MWF | Major | 28, 31 |
| *Cyperus* spp. | | F | Minor | 28 |
| *Kyllinga bulbosa* P. Beauv. | | MF | Minor | 28, 31 |
| *Mariscus sieberianus* | | F | Minor | 28 |
| **Commelinaccae** | | | | |
| *Commelina bengalensis* | | F | Minor | 28 |
| *Commelina latifolia* A. Rich. | Water maker (E) | MWF | Major | 28, 31 |
| *Commelina subulata* | | F | Minor | 28 |
| **Compositae** | | | | |
| *Acanthospermum hispidum* DC. | Starbur (E) | MW | Minor | 31 |
| *Ageratum conyzoides* L. | Goat weed (E) | MWF | Minor | 28, 31 |
| *Anthemis tinctoria* | | F | Minor | 28 |
| *Artemisia vulgaris* L. | | MW | Minor | 31 |
| *Bidens pilosa* L. | Blackjack (E) | MWF | Minor | 28, 31 |
| *Calendula Arvensis* | | F | Major | 28 |
| *Chrysanthenum segatum* | | F | Major | 28 |
| *Conyza bonariensis* (L.) Cronq. | Fleabane (E) | MF | Minor | 28,31 |
| *Crisium arvense* (L.) Scrop. | Canada thistle (E) | WF | Minor | 28, 31 |
| *Emilia sonchifolia* | | F | Minor | 28 |
| *Flaveria trinervia* (Spereng.) C. Mohr. | Goroseza (O) | | Major | 31 |
| *Galinsoga parviflora* Cav. C. Jeffery. | Gallant solider (E) | MW | Major | 31 |
| *Guizotia scarba* (Vis.) Chiov. | Mech (A) | MWF | Minor | 28, 31 |

Appendix 1. Contd.

| **Family and botanical name** | **Common name** | **Site** | **Status** | **Ref.** |
|---|---|---|---|---|
| *Lactuca serriola* Tron. | Prickly lettuce (E) | W | Minor | 31 |
| *Launaea cornuta* (Oliv. and Hiem) | Wild-lettuce (E) | MWF | Major | 28, 31 |
| *Launaea intybacea* (Jacq.) Beauv. O. Hoffm. | | MF | Minor | 28, 31 |
| *Parthenium hysterophorus* L. | Congress weed (E) | MWF | Minor | 28, 31 |
| Rich. Ex Pers.) D.C. | | | | |
| *Siegesbeckia orientalis* L. | | MW | Minor | 31 |
| *Sonchous oleraceae* | | F | Minor | 28 |
| *Sonchus asper* (L.) Hill | Spiny sow-thidtle (E) | WF | Minor | 28, 31 |
| *Sonchus exauriculatus* (Oliv. and Hiern.) | | MW | Minor | 31 |
| *Spilanthes mauritiana* | Yemder-berberi (A) | MWF | Minor | 28, 31 |
| *Tagetus minuta* L. | Mexican marigold (E) | MW | Major | 31 |
| *Traxacum officinale* Waber. | Dandelion (E) | W | Minor | 31 |
| *Xanthium spinosum* L. | Spiny cocklebur (E) | MW | Minor | 31 |
| *Xanthium strumarium* L. | Cocklebur (E) | MW | Minor | 31 |
| **Convolvulaceae** | | | | |
| *Convolvulus arvensis* L. | Bind weed (E) | MWF | Minor | 28,31 |
| *Convolvulus spp.* | | F | Minor | 28 |
| *Fallopia convolvulus* | | F | Minor | 28 |
| *Ipmomea hederifolia* | | M | Minor | 31 |
| *Ipomea acuminata* | | W | Major | 31 |
| *Ipomea carica* (L.) Sweet. | Yatir hareg (A) | MWF | Major | 28,31 |
| *Ipomea congesta* | | W | Minor | 31 |
| *Ipomea cordifana* (Desr.) Choisy | | MWF | Major | 28,31 |
| *Ipomea eriocarpa* R.Br. | | MWF | Major | 28,31 |
| *Ipomea sinensis* Choisy | | MWF | Major | 28,31 |
| **Cruciferae** | | | | |
| *Myagrum perfoliatum* | | F | Minor | 28 |
| **Cucurbitaceae** | | | | |
| *Citrulus colocynthus* (L.) Scrad. | | M | Minor | 31 |
| *Cucumis dipsaceus* Spach. | | M | Minor | 31 |
| *Cucumis pepo* | | | Minor | 28 |
| *Momordica charantia* | Yemder enbaye (A) | M | Minor | 31 |
| *Mukia* spp. | | F | Minor | 28 |
| **Equisetaceae** | | | | |
| *Equisetem arvense* L. | Fireweed (E) | W | Major | 31 |

Appendix 1. Contd.

| Family and botanical name | Common name | Site | Status | Ref. |
|---|---|---|---|---|
| **Euphorbiaceae** | | | | |
| *Acalypha crenata* Horchst. ex A. Rich | Orome (O) | MWF | Major | 28,31 |
| *Alysicarpus rugosus* (Willd.) DC | | M | Minor | 31 |
| *Euphorbia heterophylla* L. | Feremsis | MWF | Major | 28,31 |
| *Euphorbia hirta* L. (E) | Asthma weed | MWF | Major | 28,31 |
| *Euphorbia peplus* L. | | WF | Minor | 28,31 |
| *Euphorbia schimperiana* Scheele | | MW | Minor | 31 |
| *Euphorbia thymifolia* L. | | MWF | Minor | 28,31 |
| *Euphorbia undica* Lam. | | M | Minor | 31 |
| *Phyllanthus amure* L. | | MW | Major | 31 |
| *Phyllanthus maderaspatensis* L. | | M | Minor | 31 |
| *Phyllanthus spp.* | | M | Minor | 31 |
| *Phyllanthus tenellus* Roxb. | | MWF | Major | 28,31 |
| *Ricinus communis* L. | Castro (E) | MWF | Minor | 31 |
| **Fabaceae** | | | | |
| *Acacia spp.* | | MW | Major | 31 |
| *Cassia dendoniata* | | F | Minor | 28 |
| *Cassia obtusifolia* | | F | Minor | 28 |
| *Cassia tora* | | F | Minor | 28 |
| *Crotalaria deserticola* Jaub. Ex Bank. F. | | W | Major | 28 |
| *Crotalaria falcata* | | F | Minor | 28 |
| *Crotalaria juncea* L. | | WF | Major | 28,31 |
| *Crotalaria procera* (Ait.) Ait. F. | | MWF | Major | 28,31 |
| *Desmodium adscendense* | | F | Minor | 28 |
| *Indigofora amorphoides* Jaub and Spach. | | MWF | Minor | 28,31 |
| *Indigofora grackeana* Vatke | | MWF | Major | 28,31 |
| *Indigofora schemifera* | | F | Minor | 28 |
| *Indigofora spicata* Forssk. | Creeping indigo (E) | MWF | Minor | 28,31 |
| *Medicago polymorpha* L. | Thooted medic (E) | MW | Minor | 31 |
| *Mimosa pudica* L. | Sensetive (E) | WF | Minor | 28,31 |
| *Rhynchosia malacophylla* (Sprenq.) Boj. | | MWF | Minor | 28,31 |
| *Scorpiurus muricatus* L. | | MWF | Minor | 28,31 |
| *Senna occidentalis* (L.) Link. | | MW | Minor | 31 |
| *Sesbania sesban* | | F | Minor | 28 |
| *Sesbania* spp. | Sesbsnia (E) | W | Minor | 31 |
| *Trifolium rueppellianum* Fresen. | | M | Minor | 31 |
| *Trifolium* spp. | | WF | Minor | 28,31 |
| *Vicia sativa* L. | Common vetch (E) | M | Minor | 31 |
| *Vigna fisheri* Harms. | | MWF | Major | 28,31 |

Appendix 1. Contd.

| Family and botanical name | Common name | Site | Status | Ref. |
|---|---|---|---|---|
| **Gentianaceae** | | | | |
| *Enicostema axillare* (Lam.) A. Raynal | | M | Minor | 31 |
| **Gramineae** | | | | |
| *Agrostis alba* | | F | Minor | 28 |
| *Axonopus compressus* (Sw.) P.B. | Carper grass (E) | M | Minor | 31 |
| *Brachiaria eruciforma* (J.E.Sm.) Griseb | | MWF | Minor | 28,31 |
| *Cenchrus enchinatus* L. | | MW | Minor | 31 |
| *Chloris barbata*, Sw. | | MF | Minor | 28,31 |
| *Chloris phycothrix* | | F | Minor | 31 |
| *Cynodon dactylon* (L.) pers. | Bermuda grass (E) | MWF | Minor | 28,31 |
| *Cynodon nlemfuensis* Vanderyst. | Star grass (E) | MWF | Minor | 28,31 |
| *Digiraria abyssinica* (A. Rich) Stapf | Blue couch grass (E) | MW | Minor | 31 |
| *Digitaria ciliaris* (Retz.) koel | Carb grass (E) | MW | Minor | 31 |
| *Digitaria horizontalis* Willd. | | MWF | Minor | 28,31 |
| *Digitaria leptorhacis* (Pilg.) Stapf | | MW | Minor | 31 |
| *Digitaria psedodiagonalis* | | F | Minor | 28 |
| *Digitaria sanguinalis* (L.) Scop. | Large crabgrass (E) | MWF | Major | 28,31 |
| *Digitaria ternata* (A. Rich) Stapf. | Makwella (O) | MWF | Minor | 28,31 |
| *Digitaria velutina* (Forsk.) P. Beauv. | Shubbo (O) | MWF | Minor | 28;31 |
| *Dinebra retroflexa* (Vahl.) Panzer | Chew-Chewit (T) | MW | Minor | 31 |
| *Echinochloa colona* (L.) Link. | Jungle rice (E) | MWF | Minor | 28;31 |
| *Eichinochloa crus- galli* (L.) P.B. | Barnyard grass (E) | M | Minor | 31 |
| *Elusine indica* (L.) Gaertn. | Wild finger miller (E) | MW | Minor | 31 |
| *Eragrostis cilianensis* (All.) Lut. | Yewef tef (A) | MWF | Minor | 28,31 |
| *Ericola Fatmensis* (Hochst. and Steud.) W.D. | | MWF | Minor | 28,31 |
| *Heteropogon contortis* (L.) Roem and Schult. | | M | Minor | 31 |
| *Hypherrenia cynbaria* | | F | Minor | 28 |
| *Hypherrenia hirta* | | F | Minor | 28 |
| *Hypherrenia pilgerana* | | F | Minor | 28 |
| *Ischaemum afrum* (J.F. Gmel.) Dandy | | MW | Minor | 31 |
| *Panicum capillaria* | | | | |
| *Panicum deustum* | | W | Minor | 31 |
| *Panicum fassiculatum* | | MW | Minor | 31 |
| *Panicum maximum* | | F | Minor | 28 |
| *Panicum repense* L. | Torpendo grass (E) | MWF | Minor | 28,31 |
| *Paspalidium geminatum* (Forssk.) Stapf. | | M | Minor | 31 |
| *Paspalum conjugatum* | | F | Major | 28 |
| *Paspalum natatum* Fluegge | | MW | Minor | 31 |
| *Paspalum urvillei*, Steud. | | MF | Minor | 28,31 |

Appendix 1. Contd.

| Family and botanical name | Common name | Site | Status | Ref. |
|---|---|---|---|---|
| *Paspalum paniculatum* | | F | Minor | 28 |
| *Paspalum vagniatum* | | F | Minor | 28 |
| *Pennisetum cladestinum* Hichst. Ex Chiov. | Kikuyu grass (E) | MW | Minor | 31 |
| *Phalaris arudindceum* | | F | Minor | 28 |
| *Phalaris paradoxa* L. | Asendabo (A) | M | Minor | 31 |
| *Rottboellia cochinchinensis* (Lour.) W.D. | Itch grass (E) | MWF | Major | 28, 31 |
| *Rottboellia exaltata* | | F | Minor | 28 |
| *Setaria geniculata* (L.) P.B. | | MF | Minor | 28, 31 |
| *Setaria pumila* (Poir.) Roem. and Schult. | Yellow foxtail (E) | MWF | Minor | 28, 31 |
| *Setaria verticillata* (L.) P. Beauv. | Love grass (E) | MW | Minor | 31 |
| *Snowdenia polystachya* (Fresen.) Pilg. | Ethiopian grass (E) | MF | Major | 28, 31 |
| *Sorghum arundinaceum* (Desv.) Stapf | | WF | Major | 28, 31 |
| *Sorghum halepense* (L.) Pers. | Wild sorghum (E) | M | Minor | 31 |
| *Sorghum verticilliforum* (Steud.) Stapf. | | M | Minor | 31 |
| *Sporobulus jacquemonti* | | F | Minor | 28 |
| **Haloragidaceae** | | | | |
| *Myriophyllum spicatum* L. | | W | Minor | 31 |
| **Labiata** | | | | |
| *Leucas martincensis* (Jacq.) Ait. F. | Robbin weed (E) | MWF | Major | 28, 31 |
| **Liliaceae** | | | | |
| *Muscari neglectum* | | F | Major | 28 |
| *Allium spp.* | | F | Minor | 28 |
| **Lobeliaceae** | | | | |
| *Lobelia cliffortiana* L. | | WF | Minor | 28, 31 |
| **Malvaceae** | | | | |
| *Abutilon dactylon* L. | | W | Minor | 31 |
| *Abutilon theophrasti* Medicus | Velvet leaf (E) | MF | Major | 28, 31 |
| *Hibiscus oxalifolus* | | F | Minor | 28 |
| *Hibiscus panduriformis* Burn. F. | | WF | Minor | 28, 31 |
| *Hibiscus trionum* L. | Flower in an hour (E) | MWF | Major | 28, 31 |
| *Malva verticillata* L | Mallow (E) | M | Minor | 31 |
| *Sida acuta* Burn. F. | | MF | Major | 28, 31 |
| *Sida alba* L. | | MF | Minor | 28, 31 |
| *Sida ovata* L. | | W | Minor | 31 |
| *Sida rhombifolia* L. | | WF | Minor | 28,31 |
| **Myrtaceae** | | | | |
| *Eucalyptus spp.* | \ | F | Minor | 28 |
| **Nyctaginaceae** | | | | |
| *Boerhaavia erecta* L. | Tar-vine (E) | MWF | Minor | 28,31 |

Appendix 1. Contd.

| **Family and botanical name** | **Common name** | **Site** | **Status** | **Ref.** |
|---|---|---|---|---|
| **Papaveraceae** | | | | |
| *Argemone mexicana* L. | Mexican poppy (E) | MW | Minor | 31 |
| *Argemone* spp. | | F | Minor | 28 |
| *Fumaria officinale* | | F | Minor | 28 |
| **Phytolaccaceae** | | | | |
| *Phytolcea american* | | F | Minor | 28 |
| **Plantaginaceae** | | | | |
| *Plantago lancolata* L. | Gorteb (A) | WF | Minor | 28,31 |
| **Polygonaceae** | | | | |
| *Oxygonum sinatum* (Meisn.) Dammer | | MW | Minor | 31 |
| **Nyctaginaceae** | | | | |
| *Boerhaavia erecta* L. | Tar-vine (E) | MWF | Minor | 28,31 |
| **Papaveraceae** | | | | |
| *Argemone mexicana* L. | Mexican poppy (E) | MW | Minor | 31 |
| *Argemone spp.* | | F | Minor | 28 |
| *Fumaria officinale* | | F | Minor | 28 |
| **Phytolaccaceae** | | | | |
| *Phytolcea american* | | F | Minor | 28 |
| **Plantaginaceae** | | | | |
| *Plantago lancolata* L. | Gorteb (A) | WF | Minor | 28,31 |
| **Polygonaceae** | | | | |
| *Oxygonum sinatum* (Meisn.) Dammer | | MW | Minor | 31 |
| *Persicaria senegalensis* (Meisn.) Sojak | | W | Minor | 31 |
| *Polygonum avicular* | | F | Minor | 28 |
| *Polygonum nepalense* Meisn. | Yetiga Siga (A) | MF | Minor | 28,31 |
| **Portulacaceae** | | | | |
| *Portulaca quadrifida* L. | | MF | Minor | 28,31 |
| *Portulca oleraceae* L. | Purslane (E) | MWF | Major | 28,31 |
| *Protulaca rotundifolia* L. | | M | Minor | 31 |
| **Primilaceae** | | | | |
| *Anagallis arvensis* L. | Primpernil (E) | M | Minor | 31 |
| **Ranuculaceae** | | | | |
| *Climatis simensis* | | F | Minor | 28 |
| *Ranuculus arvensis* | | F | Minor | 28 |
| **Resedaceae** | | | | |
| *Caylusea abyssinica* (Fresen.) Fisch. and May. | | MW | Minor | 31 |

Appendix 1. Contd.

| Family and botanical name | Common name | Site | Status | Ref. |
|---|---|---|---|---|
| **Rubiaceae** | | | | |
| *Galium spurium* L. Var. africanum Verdc. | Cleaver (E) | M | Minor | 31 |
| *Gardenia ternifolia* | | F | Minor | 28 |
| *Oldendandia offinis* | | F | Minor | 28 |
| *Paederia foetida* L. | | W | Minor | 31 |
| **Sapindnceae** | | | | |
| *Cardiospermum halicacabum* L. | | MWF | Minor | 28,31 |
| **Scrophulariaceae** | | | | |
| *Lindennia dubia* | | F | Minor | 28 |
| **Solanaceae** | | | | |
| *Datura stramonium* L. | Thorn apple (E) | MWF | Major | 28,31 |
| *Lycopersicum* L. | Tomato (E) | MWF | Minor | 28,31 |
| *Nicandra physalodes* Scop. | Chinese lanter (E) | MWF | Minor | 28,31 |
| *Solanum hastifolium* Hochst. Ex Dunal | | MW | Minor | 31 |
| *Solanum incanum* L. | Sodom apple (E) | MF | Minor | 28,31 |
| *Solanum nigrum* L. (E) MWF | Black night shade (E) | MWF | Minor | 28,31 |
| **Stericulaceae** | | | | |
| *Melhaniaovata* (Cav.) Spreng. | | M | Minor | 31 |
| **Tiliaceae** | | | | |
| *Corchorus pseudocapsularis* Schewinf. | | MF | Minor | 28,31 |
| *Corchorus trilocularis* L. | Humera-weed (E) | MWF | Major | 28,31 |
| *Triumfetta lappula* | | M | Minor | 31 |
| **Umbelliferae** | | | | |
| *Bifora radians* Bieb. | | WF | Minor | 28,31 |
| *Dacus carrota* | | F | Minor | 28 |
| *Hydrocotyle bonariensis* | | F | Major | 28 |
| **Verbenaceae** | | | | |
| *Lantana camara* L. | Lantant (E) | WF | Minor | 28,31 |
| *Stachytapheta jamaicensis* (L.) Vahl. | | M | Minor | 31 |
| *Verbena officinalis* L. | | M | Minor | 31 |
| **Zygophyllacene** | | | | |
| *Tribulus terrestris* L. | Puncture vine (E) | MW | Minor | 31 |

E= English, A= Amharic, O= Oromifa, T= Tigrigna, W= Wonji-Shoa, M= Metahara, F= Finchaa, WF = both Wonji-Shoo and Finchaa, MF= Both Metahara and Finchaa, WMF = all the three plantations.

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# Pest Problems and Their Management Practices in Flower Farms in Ethiopia

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## Introduction

Historically, commercial flower production in Ethiopia started in the mid 1980s by the state owned farms, namely Upper Awash Agro-Industry Enterprise (UAAIE) and Horticulture Development Enterprise (HDE) on a land area not more than 150 hectares. However, the production and marketing of flowers dwindled significantly, having shrunk to a production area of less than 10 ha by the turn of the century. Since the shift of the floriculture industry from the state to private ownership, the sector is expanding at a very fast rate (Adhanom, 2006). Consequently, Ethiopia is earning substantial amount of foreign currency that reached 8 Million USD in the year 2006 from the sales of flowers alone (ECA, 2007). Likewise, over 30,000 workers were employed in the sector (Anonymous, 2007b). In 2000 EC (2008) alone, the total area occupied by flowers (tunnel and greenhouses) was about 1200 ha, the amount of foreign currency obtained was over 100 million USD, and employed over 45,000 workers (Ethiopia Horticulture Producers and Exporters Association (EHPEA), April 2009, personal com.).

Obviously, flowers are among most sensitive commodities to diseases and insect pests, but research on flower protection in Ethiopia is almost at its enfant stage. A number of diseases that affect cultivated roses in open fields were recorded by Stewart and Dagnatchew (1967), and more recently Eshetu *et al.* (2009) recorded diseases of most ornamental plants grown in the country. In addition, many insect pests and mites that damage ornamental plants were also recorded in recent years (PPRC, 2005; Eshetu *et al.*, 2009; PRC, unpublished).

Like in other flower producing countries of Africa (e.g. Kenya, Tanzania and Uganda) and Latin America (Colombia), the management of most flower pests depends on synthetic pesticides. However, there are no pesticides registered for flower pests following the formal registration process in Ethiopia, and hence,

pesticide availability and regulation was not so effective. Considering the urgency of this problem, the Ethiopian Government made an interim arrangement for flower growers to import pesticides and other chemicals required for their own farms without restrictions. As a result, flower growers have been importing many different kinds of pesticides for use in routine pest control activities. Although this arrangement was important to solve the problem temporarily, it cannot be long lasting solution as importing such diverse pesticides by many individual growers will have a serious problem in the future. Hence, it was felt necessary to assess pesticides being used by flower farms and recommend for formal registration that may finalize the interne arrangement and provide legal frame for pesticide regulation to protect the country from pile of obsolete pesticides and pollution. The Pesticide Research Committee (PRC) of EIAR took an assignment to assess pesticides being used by the different flower farms so that those pesticides which were being used by most farms and meet the requirements will be suggested for registration.

This review paper presents and discusses diseases and insect pests recorded in the country; management practices followed by most farms, chemical pesticides used; and suggest future research directions for flower pest management in this country.

# Research findings

## Pests of ornamental plants in Ethiopia

The number of flower farms in Ethiopia currently is over 200 and the cultivated area under greenhouses reached over 1000 ha. Major flowers grown in these farms include roses, *Hypericum*, *Eryngium*, carnations, *Gypsophylla*, *Chrysanthemum*, *Geranium* cutting and over 100 other bed plants (Eshetu *et al.* 2009; Morris, 2006). Over 77% of these farms produce roses on 74% of the land area while 5.7% of the farms produce mainly carnation, *Gypsophylla* and *Geranium*, and other bed plants on the rest of the land area allotted to flowers (Eshetu *et al.*, 2009). Although flower production and export has tremendously increased in the last few years, with the increase in flower farms and flower production the number and severity of disease and insect pests also increased significantly.

## Diseases

Stewart and Dagnatchew (1967) recorded a number of diseases on cultivated open field roses in different parts of Ethiopia. However, none of them were known to be severe. Recent surveys by Eshetu *et al*. (2009) revealed some more important diseases of different flowers in the country (Table 1). By comparing these two records, there was a difference in pathogen spectrum on roses.

Important diseases such as downy mildew, dieback, canker and root knot nematodes were not recorded 40 years ago in open field roses while leaf spot caused by *Septoria rosae* and leaf mold caused by *Cladosporium fuscum* were not observed at present (Eshetu *et al*., 2009). Depending on the frequency of occurrence and importance, Eshetu *et al*. (2009) grouped diseases of flowers into major, medium and minor status. Their importance was also reported to vary with seasons. The survey made during the rainy and dry seasons of 2004 in 12 rose farms (Table 2) showed that gray mold (*Botrytis cinerea*), downy mildew (*Peronospora sparsae*) and powdery mildew (*Sphaerotheca pannosa* var. *rosae*) were the most common on roses at different farms (PPRC, 2005). Gray mold and downy mildew were more important in the rainy season when the humidity was generally high while powdery mildew was common in the dry season.

Any sign of disease on the flower heads or leaves render the flowers unacceptable by importers resulting in losses; hence, intensive care was reported to be necessary in all of the farms. More specifically, downy mildew was a serious problem at Enyi farms, apparently causing a complete loss of one cycle harvest in a half-hectare greenhouse. Gray mold affects the petals of roses and make the flowers unmarketable. It reduced also the vase life of flowers, which again is one of the quality parameters of cut flowers (PPRC, 2005). Crown gall was serious at the Golden Roses Agro farm with incidences varying from 60-95% in the entire greenhouse. It was also recorded in Ethio Dream, though the incidence was trace (Table 2). Although crown gall was recorded before 40 years in Ethiopia, the infestation of all farms in such a relatively short time indicates that either the inoculum might have been imported with planting materials from Kenya and South Africa, which were the sources of planting materials or widespread presence of these susceptible hosts might stimulated the rapid multiplication of the pathogen. Once it is established in the soil, it is difficult to eradicate (Morris, 2006), and hence, quarantine measures on imported planting materials are extremely important and is timely in the floriculture sector at present.

Table 1. Diseases and their causal pathogens recorded on different flower plants.

| Causal agent | Diseases | Flowers attacked | Status | Ref. |
|---|---|---|---|---|
| *Peronospora sparsa* | Downy mildew | Roses | major | |
| *Sphaerothecamacularis** | Powdery mildew | Roses | major | 11 |
| *Sphaerotheca pannosa* var. *rosae* | Powdery mildew | Roses | major | 5 |
| *Oidium* sp. | Powdery mildew | Roses | major | 11 |
| *Botrytis cinerea* | Gray mold | Roses | major | 5,11 |
| *Diplocarpon rosae* | Black spot | Roses | minor | 5,11 |
| *Phragmidium* spp. | Rust | Roses | minor | 5 |
| *Phragmidium* disciflorum | Rust | Roses | minor | 11 |
| *Phragmidium mucronatum* . | Rust | Roses | minor | 11 |
| *Uredo* sp. | Rust | Roses | minor | 11 |
| *Agrobacterium tumefaciens* | Crown gall | Roses | minor | 5,10,11 |
| *Diplodia* sp. | Dieback | Roses | minor | 5 |
| *Coniothyrium* spp. | Cankers | Roses | minor | 5 |
| *Septoria rosare* | Leaf spot | Roses | unknown | 11 |
| *Cladosorium fuscum* | Leaf mold | Roses | unknown | 11 |
| *Fumago* sp. | Sooty mold | Roses | unknown | 11 |
| *Cicinnobolus cesatii* | - | Hyperpar** | unknown | 11 |
| *Eudarluka austrlis* | - | Hyperpar*** | unknown | 11 |
| *Meloidogyne* spp. | Root knot nematodes | Roses | minor | 5 |
| *Rhizoctonia solani* | Stem rot | *Hypericum* | major | 5 |
| *Fusarium oxysporum* f.sp. *dianthi* | Wilt | *Hypericum* | major | 5 |
| *Botrytis cinerea* | Blight | *Hypericum* | major | 5 |
| *Rhizoctonia solani* | Stem rot | Carnation | major | 5 |
| *Fusarium oxysporum* f.sp. *dianthi* | Wilt | Carnation | major | 5 |
| *Botrytis cinerea* | Blight | Carnation | major | 5 |
| *Fusarium* spp. | Stem rot | Carnation | minor | 5 |
| *Erysiphe* sp. | Powdery mildew | *Geranium* | major | 5 |
| *Botrytis cinerea* | Blight | *Geranium* | major | 5 |
| *Rhizoctonia solani* | Root and crown rot | *Geranium* | major | 5 |
| *Pythium ultimum* | Root and crown rot | *Geranium* | major | 5 |
| *Phytophthora* spp | Root rot | *Geranium* | major | 5 |
| *Alternaria tenuis* | Leaf spot | *Geranium* | minor | 5 |
| *Rhizoctonia solani* | Stem rot | *Gypsophilla* | major | 5 |
| *Fusarium oxysporum* | Wilt | *Gypsophilla* | major | 5 |
| *Phytophthora parasitica* | Crown rot | *Gypsophilla* | major | 5 |
| *Meloidogyne* spp | Root knot nematode | *Gypsophilla* | minor | 5 |
| *Botrytis cinerea* | Gray mold | *Chrysanthemum* | major | 5 |
| *Erwinia chrysanthemi* | Bacterial blight | *Chrysanthemum* | major | 5 |

***** perfect stage, ** hyperparasite on *Odium*, *** hyperparasite on *Phragmidium*.

Table2. Relative importance of rose diseases recorded in some farms in the 2004.

| Location/farm | Disease | Incidence (%) |
|---|---|---|
| Addis Alem/ Ethio Dream | Powdery mildew | 65 |
| | Downey mildew | 20 |
| | Gray mold | 5 |
| | Rust | trace |
| | Crown gall | trace |
| Menagesha/Menagesha Flowers | Gray mold | trace |
| | Powdery mildew | 6 |
| | Downy mildew | 5 |
| Tefki/ Golden Roses | Crown gall | 70 |
| | Downey mildew | 30 |
| | Powdery mildew | 10 |
| | Gray mold | trace |
| Sebeta/ Enyi Farms | Downey mildew | 75 |
| | Powdery mildew | trace |
| | Gray mold | 5 |
| Wonji/ Summit Agro-Industry | Powdery mildew | 40 |
| | Gray mold | 5 |
| | Downey mildew | 7 |
| | Rust | 6 |

Source: PPRC, 2005

## Insect pests

Pest survey was carried out in seven flower farms during the dry and wet seasons of 2004 (PPRC, 2005). The status of infestations were categorized as low, moderate and heavy when 20, 40 and 60% leaf damages were observed. Almost all of the arthropod pests recorded were reported to be of major importance on all flowers. Only aphids, thrips and caterpillars on roses, and thrips and caterpillars on Geranium and other bed plants were reported to be of medium importance. The only pest recorded to be of minor significance was the cotton aphid on Geranium and other bed plants. However, intermediate infestation levels were not clearly stated. Insect pests recoded in the different farms were soft wax scale (*Ceroplastes* sp.), aphids (*Aphis gossypii*), caterpillars (*Spodoptera exigu*), thrips (*Frankliniella occidentalis)*, whiteflies, red spider mites and two spotted spider mites (Table 3). Some unidentified species of beetles, whiteflies, aphids, and caterpillars were also observed in some farms. Two-spotted spider mite (*Tetranychus urticae*) was recorded only at Summit Agro-Industry. Major damage in these farms was inflicted by spider mites followed by flower thrips and aphids. These pests were reported to be commonly found both in the wet and dry seasons, although spider mites were reported to be more prevalent in the dry season (PPRC, 2005). It was also reported that there was an indication of resistance development in the red spider

mite to pesticides at the Ethio Dream and Menagesha farms. This alarm signal should be considered seriously. Insect pests of different flowers recorded during the 2006 survey are presented in Table 4. Some previously reported (PPRC, 2005) insect pests namely *Spodoptera exempta*, *Ceroplastes* sp., *Frankliiniella* sp., and *Helicoverpa* sp. were not observed in this latest assessment (Eshetu *et al*, 2009) probably due to the sporadic nature of these insects. Moreover, both PPRC (2005) and Eshetu et al. (2006) did not record the arthropods reported by Tsedeke (1988) on roses, except the white fly (*Trialeurodes vaporarium*). In addition, most of the common pests found in the recent records were not known in the past.

Table 3. Insect pests recorded on different rose varieties grown in different farms in the 004 (PPRC, 2005).

| Farm name | Rose variety | Scientific name | Common name | Status |
|---|---|---|---|---|
| Ethio Dream | Bolero, Royal Baker | *Pononychus* sp. | Red spider mite | Moderate |
| | Shakira, Lovely Red | *Pononychus* sp. | Red spider mite | Heavy |
| | Terekota, Black Baccara | *Aphis gossypii* | Cotton aphid | Moderate |
| Menagesha Flowers | Gypsy, unidentified | *Pononychus* sp. | Red spider mite | Heavy |
| | Jupiter | *Pononychus* sp. | Red spider mite | Moderate |
| | Jupiter | *Aphis gossypii* | Cotton aphid/ aphids | Low |
| Golden Rose | Shanti | *Pononychus* sp. | Red spider mite | Moderate |
| | Shanti | *Aphis gossypii* | Cotton aphid | Low |
| | Shanti | *Frankliiniella* sp. | Flower thrips | Low |
| | Golden Gate | *Pononychus* sp. | Red spider mite | Low |
| | Golden Gate | *Frankliiniella* sp. | Flower thrips | Low |
| | Golden Gate | ? | Aphid | Heavy |
| Enyi Ethio Rose | unidentified | *Frankliiniella* sp. | Flower thrips | Serious* |
| | unidentified | *Pononychus* sp. | Red spider mite | Low |
| Summit Agro-Industry | Golden Gate | *Tetranychus utricae* | Two-spotted spider | Heavy |
| | Golden Gate | *Pononychus* sp. | Red spider mite | Heavy |
| | Golden Gate | *Spodoptera exempta* | Army worm | Low |
| | Golden Gate | *Ceroplastes* sp. | Soft wax scale | Low |
| | Canola | *Frankliiniella* sp. | Flower thrips | Low |
| Mulo Flower | unidentified | *Helicoverpa* sp. | Bollworm | Low |
| | unidentified | *Frankliiniella* sp. | Flower thrips | Low |
| SIET Agro | Duwett | *Pononychus* sp. | Red spider mite | Moderate |
| | Duwett | *Aphis gossypii* | Cotton aphid | Moderate |
| | Alloha | *Pononychus* sp. | Red spider mite | Moderate |
| | Alloha | *Aphis gossypii* | Cotton aphid | Low |

Low = up to 20% infestation, Moderate = about 40% leaf damage, Heavy = about 60% leaf damage. *Serious when it rains

Unidentified species of beetles, caterpillars and white fly were recorded at low status in the Summit Agro-Industry farm on rose variety Golden gate.

Table 4. Arthropod pests recorded on different flowers in Ethiopia.

| Scientific name | Common name | Flowers attacked | Ref. |
|---|---|---|---|
| *Tetranychus urticae* | Two-spotted spider mite | Roses, *Gypsophylla*, *Chrysanthemum* | 5, 10,11 |
| *Pononychus* sp. | Red spider mite | Roses, *Gypsophylla*, *Chrysanthemum* | 5, 10,11 |
| *Frankliiniella* sp. | Flower thrips | Roses, *Hypernicum*, Carnation, *Geranium* and other bed plants, *Gypsophylla*, *Chrysanthemum* | 5, 10,11 |
| *Aphis gossypii* | Cotton aphid | Roses, *Hypernicum*, Carnation, *Geranium* and other bed plants, *Gypsophylla*, *Chrysanthemum* | 5, 10,11 |
| Different species | Caterpillars | Roses, *Geranium* and other bed plants | 5, 10,11 |
| *Trialeurodes vaporarium* | White fly | *Hypernicum*, Carnation, *Geranium* and other bed plants, Rosa spp. | 5, 10,11, 12 |
| ? | Flea beetles | *Hypernicum*, *Geranium* and other bed plants | 5, 10,11 |
| *Bradysia* spp. | Sciaride flies | *Geranium* and other bed plants | 5, 10,11 |
| ? | Leaf hoppers | *Gypsophylla* | 5, 10,11 |
| Termite spp. | Termites | *Gypsophylla* | 5, 10,11 |
| *Liriomyza* spp. | Leaf minors | *Gypsophylla* | 5, 10,11 |
| *Agrotis* spp. | Cut worms | *Chrysanthemum* | 5, 10,11 |
| *Aonidiella aurantii* | Red scale | *Rosa* spp., *Rosa abyssinica* | 13 |
| *Aphis craccivora* | Groundnut aphid | *Rosa* spp., *Rosa abyssinica* | 13 |
| *Chaelosiphon tetrarhodus* | Rose aphid | *Rosa* spp., *Rosa abyssinica* | 13 |
| *Icerya purchasi* | Cottony cushion scale | *Rosa* spp., *Rosa abyssinica* | 13 |
| *Macrosiphum porosum* | Aphid | *Rosa* spp., *Rosa abyssinica* | 13 |
| *M. rosae* | Rose aphid | *Rosa* spp., *Rosa abyssinica* | 13 |
| *M. euphorbiae* | Pepper aphid | *Rosa* spp., *Rosa abyssinica* | 13 |
| *Monolepta intermedia* | Four-spotted rose beetle | *Rosa* spp., *Rosa abyssinica* | 13 |
| *M. puncticeps* | Rose beetle | *Rosa* spp., *Rosa abyssinica* | 13 |
| *Pachnoda abyssinica* | Yellow rose chafer | *Rosa* spp., *Rosa abyssinica* | 13 |
| *P. massajae* | Yellow-headed chafer | *Rosa* spp., *Rosa abyssinica* | 13 |
| *P. stehelini* | Rose chafer | *Rosa* spp., *Rosa abyssinica* | 13 |
| *P. thoracica* | Rose chafer | *Rosa* spp., *Rosa abyssinica* | 13 |
| *Pantomorus godmani* | Fuller rose beetle | *Rosa* spp., *Rosa abyssinica* | 13 |
| *Pseudaphis abyssinica* | Abyssinian aphid | *Rosa* spp., *Rosa abyssinica* | 7,13 |
| *Tetranychus cinnabarinus* | Red spider mite | *Rosa* spp., *Rosa abyssinica* | 13 |

## Disease management practices in the farms

Gary mold, downy mildew, powdery mildew and other fungal diseases were regularly monitored in all of the farms, mainly by identified scouts (Eshetu *et al*., 2009; Morris, 2006). Generally, sanitation was carried out every 3 to 4 days against most diseases. Some cultural practices such as ventilation (at relative humidity over 70%), removal of stressed plants, reduction of plant density, bending branches and washing were reported to be practiced in order to control diseases such as powdery mildew and downy mildew. General sanitary measures such as removing infected plants, plant residues and keeping appropriate hygiene of the operators and tools were believed to have great impact on the health of flowers. Thus, all flower farms carry out rigorous preventive programs to combat diseases using fungicides. They also used curative fungicides based on the intensity of the disease at particular time. Pesticides used by the different farms for the control of different diseases are presented in Appendix 1. Spot application of fungicides was reported to be practiced when pest infestations were localized at certain spots in the greenhouse and general applications were carried out more often. Sulfur burning was carried out by some growers, predominantly for the control of powdery mildew, while ULV applicators were used to apply a preventive fungicide onto all flowers prior to and during cold storage to combat botrytis (Morris, 2006).

Unlike other foliar diseases, management of crown gall was carried out by using copper hydroxide and a range of cultural control methods such as pulling out and burning diseased plants, use of free planting materials (Morris, 2006; PPRC, 2005). Crown gall caused by *Agrobacterium tumefaciens* is expected to become a more serious problem in the near future for Ethiopian rose industry, if healthy planting materials are not used and proper sanitation procedures are not practiced in all the farms.

## Pesticides suggested for registration

The Pesticide Research Committee (PRC) of EIAR with the consent of the regulatory department (Animal and Plant Health Regulatory Directorate of the Ministry of Agriculture and Rural Development) was given the assignment to assess flower farms and their pesticide uses. This was to recommend pesticides for registration based on secondary data and users' opinion on their efficacy. The assessment revealed that 104 fungicides were used to control flower diseases in the year 2006. Out of these, 65 fungicides were recommended for registration (Appendix 1). These fungicides were commonly used by most of the farms. Furthermore, these products were accepted since they were found in MPS-Code List 2006 (/Kenya, Tanzania, Uganda); one product found in MPS-

Code List Holland, three products registered in MPS-Code List of Ethiopia, and four products registered in Kenya (Eshetu *et al.*, 2009).

## Research on flower disease management

The research system lacks appropriate greenhouse and related facilities for conducting research on flower pest management at present. Only limited verification trials were carried out in the country. Out of these, three fungicides namely Systhan 20 EW (Myclobutanil) against powdery mildew, Funguran-OH 50 WP (copper hydroxide) against downy mildew and Electis 75 WG (Zaxamide 8.3% + Mancozeb 66.7%) against botrytis were tested in 2005 in greenhouses of Ethio Dream, Menagesha and Enyi farms. Since the experiments were carried out in production greenhouses, the interference of the routine farm practices carried out by the farms created difficulty to obtain appropriate and accurate efficacy data on the pesticides, and hence, the trials were interrupted (Eshetu, 2006).

## Insect pest management in the farms

Monitoring for spider mites was carried out on a regular basis. All farms reported to use acaricides at 4-10 days spray interval (Eshetu *et al.*, 2009; Morris, 2006; PPRC, 2005). Mohammed et. al. (2008) reported that over 20 pesticides were used to control mites in flower farms. List of acaricides/ insecticides are presented in Table 5 and Appendix 2. The cost of acaricides was reported to be about 40% of the total amount spent on pesticides. The efficacy of these products is reported to be decreasing from time to time. Pesticide resistance was suspected for the decline in efficacy. This situation initiated some farms to introduce biological control using natural enemies. Anon. (2007a) reported that experiments were initiated on five farms to evaluate two introduced predators *Phytoseiulus persimilis* and *Amblyseius swirskii*. Mohammed et. al. (2008) reported the performance of three predatory mites introduced from the Koppert Company in the Netherlands with the assistance of the Embassy of the Netherlands and Wageningen University. Results of this trial are summarized under the biological control section of this paper.

Adequate watering of plants during dry conditions can limit the importance of drought stress on spider mite outbreaks. Periodic hosing of plants with a forceful jet of water can physically remove and kill many mites, as well as remove the dust that collects on foliages and interferes with mite predators. Disruption of the webbing also appear to delay egg laying until new webbing is produced (PPRC, 2005).

Table 5. Insecticides used against various insect pests of roses at different flower farms in Ethiopia.

| Farm | Insect pests | Insecticides |
|---|---|---|
| Ethio Dream | Thrips | Lannate |
| | Red spider mite | Dimethoate, Apollo, Dicofol and Karate |
| Menagesha Flower | Red spider mite, aphids | Thiodan, Pegasus, Mitac, Acrimactin, Acrimite, Neoron 250, Dynamic, Rufast, Perapal |
| Golden Rose | Red spider mite | Apollo, Magister, Mitac, Torque, Nissorun, Peropal, Dynamic, Mitigan |
| | Thrips | Confidor, Diazinon |
| | Aphids | Diazinon |
| Eniyi Ethio Rose | Thrips | Diazinon, Confidor, Orthene |
| | Red spider mite | Dynamic, Pegasus, Selecron, Peropal |
| Summit Agro-Industry | Two-spotted spider mite | Selecron & Dynamic |
| | Red spider mite | Apolo (ovicide) |
| | Soft wax scale | Methomyl, Lannate, Confidor |
| SIET Agro | Red spider mite | Dynamic, Selecron |
| | Aphids | Thionex |

Source: PPRC, 2005

Thrips, aphids, whiteflies, sciarid flies (fungus grats), flea beetles, caterpillars, soft scales were found to be important insect pests. Based on the regular monitoring, thrips and aphids, sciarid flies and flea beetles were reported to be of major to medium importance on different flowers (Tables 3 and 4). Several other insect pests were reported to be occasional pests of minor importance. According to the reports of the farms, depending on the level of expertise, each farm tries to alter the type of insecticides after each application in order to reduce resistance development by pests (Eshetu *et. al.,* 2009; Morris, 2006; PPRC, 2005).

Of the 96 insecticides, acaricides and nematicides being used by the farms, 77 (80.2%) products were recommended for registration. Out of the 77 products 71 are found in MPS-Code List 2006 /Kenya, Uganda, Tanzania/; three products selected since they are found in MPS-Code List 2006 Holland; one product is in the MPS-Code List 2005 of Ethiopia and two products due to their registration in Kenya (Appendix 2).

## Herbicides and plant growth regulators

Besides diseases and insect pests, weeds are also problems in some farms especially when open fields are used for flower production like *Gypsophylla*, *Hypericum* and *Eryngium*. Moreover, stickers were used as an additive to pesticides for a better efficacy. Hormones and post harvest-handling chemicals for rooting and other purposes are also used. Therefore, four stickers, 12

hormones, 3 post-harvest handling agents, 1 pH reducer and five herbicides were found to be used by growers during the 2006 survey. From these, 2 stickers, 12 hormones, 3 post-harvest handling agents, 1 pH reducer and two herbicides were recommended for registration (Table 6).

Table 6. Stickers/adjuvants, hormones, post-harvest handling agents, pH reducer and herbicides recommended by PRC for registration (after Eshetu *et al.,* 2008).

| **Active ingredient** | **Trade name** | **Type** |
|---|---|---|
| Oxidiazon | Ronstar | Herbicide |
| Glyphosate | Round up | Herbicide |
| Fatty acids, glycol ethers | Biofilm | Sticker |
| Wetting/spreading | Supafilm | Sticker |
| Silver thiosulfate 0.8 | STS | Post harvest handling agents |
| | Tamilage tablets | Post harvest handling agents (cold room) |
| Thiobendazole 75, HQS-Hydroxi Quinolin 35, Ammonium chloride 40 | Tog 3 | Post harvest handling agents |
| Ethylene | Atryl | Hormone |
| 4-indol-3-yl-butric | BB5 | Hormone |
| Giberellic acid | CCC | Hormone |
| 4-indol-3-yl-butric acid | Chryzostop green | Hormone (rooting powder) |
| - | Diazidamon | Hormone |
| Indol acetic acid | Homoril | Hormone |
| Giberellic acid | Tivag/ GA3 Berelex/ GA3 Valioso | Hormone |
| Gebberelin + Vitamin | Gerasol | Anti stress agent |
| Paclabutazol | Cultar | Growth control |

# Biological control

The Plant Protection Research Center at Ambo (EIAR) imported three predatory mites from the Netherlands Koppert Company in May 2007. The predators introduced were *Phytseiulus persimilis, Amblyseius californicus* and *A. swirisskii*. The importation and researches were facilitated by the Embassy of the Netherlands in Addis Ababa and the Wageningen University. The trials on the adaptability and efficiency of the predators were conducted in the Et-Highland Flora Plc.and J. J. Kothari commercial rose farms between November 2007 and September 2008.

The predators were released at about 1-2 weeks interval in the Et-Highland Flora farm. Their establishment was poor at the beginning owing to low temperature and low population of the predators released compared with that of the pest. Corrective measures that include two consecutive full cover acaricide sprays followed by some spot applications were needed to reduce the pest

population. At the same time three heavy dose of *P. persimilis* and *A. californicus* were released. As the result, the predators started to establish and increased rapidly that eventually led to a quick reduction of the pest population (Fig.1 and 2). Afterwards, small releases of both predator species were made every two weeks to maintain a small 'army' that attacked the spider mites at early stages resulting in no requirement for acaricide application for the period of seven months. The pest population on the skirts (the lower leaf package) and flower stems reduced close to zero in the bio-control, while in the conventional acaricide treatments it increased close to 100% (Fig.1).

At J.J. Kothari farm the establishment of the predators was apparent three weeks after their release in December 2007 (Fig. 3). A biological balance of the pest and predator populations was established soon after this period in February 2008. Releases of the predatory mites were relatively high at this time which resulted in gradual decrease of the spider mite population. Subsequently, lower rate of releases were made every two weeks. Eventually, the infestation level reduced to a constant population of 10 - 20% in the bio-control treatments (Mohammed *et al.*, 2008).

Generally, among the predators *P. persimilis* developed rapidly and overtook the pest population quickly at both farms. However, its performance was sub optimal when the temperature was above 30°C. On the other hand, *A. californicus* developed slowly and steadily and performed well under sub optimal temperatures. It was observed that *A. californicus* developed well at temperature limits of 10-33°C. In the wet seasons this predator appeared to provide basic control at the initial stage to slow down the beginning population of spider mites.

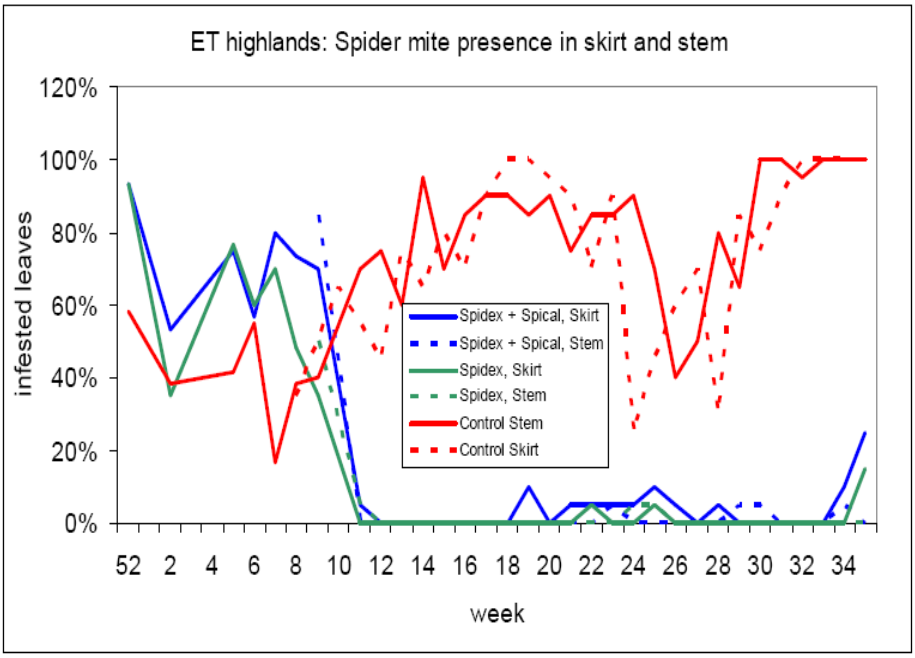


Fig.1. Population development of spider mite in IPM and control greenhouse roses at Et-Highland Flora farm (Mohammed *et al*., 2008).

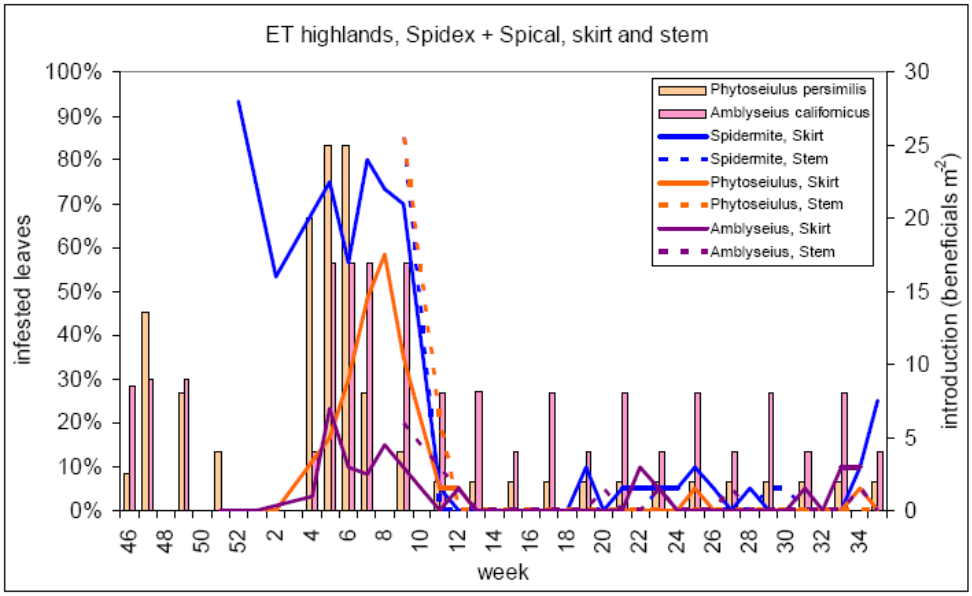


Fig. 2. Development of spider mite and predatory mites introduced in IPM greenhouse at Et-Highland Flora farm (Mohammed *et al*., 2008).

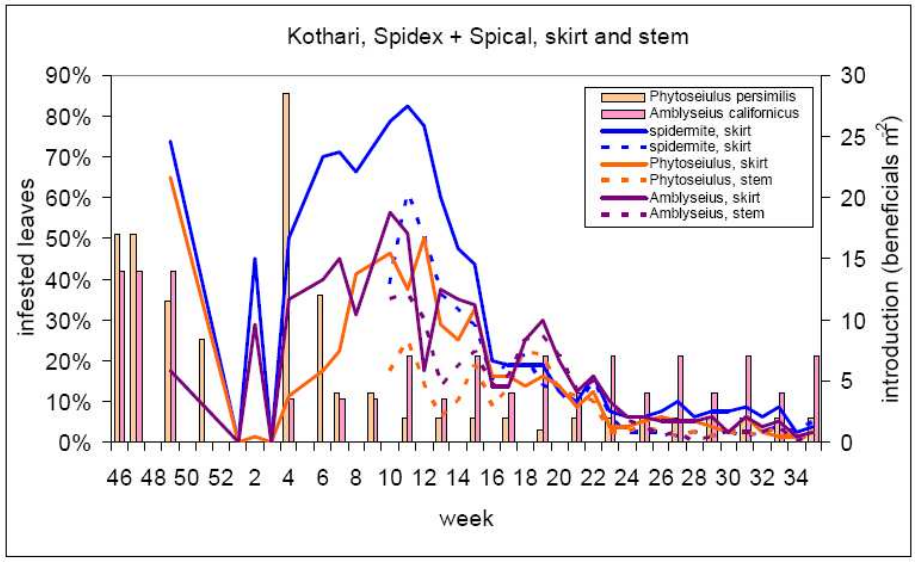


Fig. 3. Population development of spider mite and predatory mites introduced in IPM greenhouse at J. J. Kothari farm (Mohammed *et al*., 2008).

# Conclusion and recommendations

Floriculture is making remarkable contributions to the national economy through creating employment opportunities, foreign currency earning, and inculcation of new ideas to investment and diversification of commercial enterprises in Ethiopia.

Disease and insect pests are increasingly becoming threats to ornamental plants grown in greenhouses. Important and potentially serious diseases of ornamental plants include crown gall, gray mold, downy mildew and powdery mildew, root rots, rust and bacterial blight. Proper management practices that include cultural, use of resistant varieties, biological control, and chemical pesticides could support sustainable flower production. Moreover, flower growers are advised to use pest free planting materials to establish new farms and greenhouses. In addition, a stringent quarantine inspection and post-entry follow up of imported planting materials is required.

Red spider mites, aphides, thrips and caterpillars are major arthropod pests found in every farm in the country. Pesticides are the major control options at present, although biological options are being introduced in some farms. Due to the intensive use of pesticides, there are indications of resistance development in spider mites to acaricides. Hence, alteration of various acaricides with different mode of actions should be practiced. Moreover, instead of relying on

pesticides alone, cultural practices such as sanitation and ventilation should be practiced as complementary means of pest management in flower farms. Research on biological control of major pests such as spider mites should be strengthened, and the results reported from the Et-Highland Flora and J. J. Kothari farms should be confirmed in other farms.

It is obvious that the World market (especially Europe and USA) demands high quality standards to be met for agricultural produce in general. The environmental concern is also getting critical, limiting the indiscriminate use of chemical pesticides. Therefore, relatively less hazardous pesticides should be registered and their use should be regulated in order to protect the country from stockpiles of obsolete pesticides. It should be recalled that the country was forced to spend a lot of foreign currency for the disposal of obsolete pesticides few years ago.

Since research institutions lack the necessary facilities to generate local efficacy data for flower pesticides in the short term, selected pesticides from among those which are being used by the farms should be registered as soon as possible. It is hoped that this will minimize the unlimited importations and the informal marketing of pesticides for the sector in the country. Meanwhile research institutions should avail the necessary facilities for pesticide research that would enable the generation of local efficacy data for the formal registration procedures.

## Gaps and challenges

- It has been observed that all of the flower farms are dependent on chemical pesticides for the management of pests, and applications are made at blanket. Such injudicious use of pesticides, if continued, would create serious problems to the sector in the near future. The problems could be manifested in different ways such as:
  - pests could develop resistance to chemical pesticides,
  - increased application of chemicals could limit the acceptability of flowers in the world market (especially in the USA and Europe), as producers are required to adhere to the codes of practices which include minimum application of chemical pesticides,
  - high health risk to workers due to long time and repeated exposure to the pesticides, and
  - overall effects of chemicals on the environment.
- The difficulty to conduct experiments in commercial greenhouses because of interferences by routine chemical applications calls for an urgent

measures to build greenhouses and associated facilities in representative sites in the research system.

- The majority of employees in almost all of the farms seem to lack adequate knowledge and experience in plant protection in general and pesticide handling and use in particular.
- Taxonomists who can correctly identify disease causing pathogens and insects are lacking in the country.

## Prospects

- The research system should support this growing sector of the economy in finding alternative options of pest management that suit to local conditions.
- Since synthetic pesticides will remain as important components of pest management, new generation pesticides should be tested and registered for use in the country, and should be available in the formal market
- Introduction and adaptation of effective bio-control agents should be given due attention
- Collection, identification and evaluation of parasitoids and predators as well as entomopathogenic microbes and microbial agents in the greenhouses deserve adequate attention
- Appropriate courses should be given in floriculture and plant protection at different levels in the universities.
- IPM is the best option for floriculture, as it is for other crops, hence research should give due attention to this area.
- Researchers should work in close collaboration with the flower farms, give periodical trainings on pest management and pesticide use, etc.

Appendix 1. Fungicides recommended by the Pesticide Research Committee of EIAR for registration (April 2006).

| Active ingredient | Trade name | Target pests |
|---|---|---|
| Azoxystrobin | Amistar 250 SC / Ortiva SC | Rust, Botrytis, downy mildew |
| Benalaxyl+Mancozeb | Galben 8-65 WP | Downy mildew, Botrytis |
| Benomyl | Benlate/ Benomilo 50 WP/ Benomyl | Downy, powdery mildew, Botrytis, Fusarium, soil borne diseases |
| Bitertanol | Baycor 300 EC | Powdery mildew |
| boscalid+keroxym-methyl | Collis | Powdery mildew |
| Buprimate | Nimrod 25 EC | Powdery mildew |
| Captan | Captan 83/ Merpan 83 WP | Botrytis, Fusarium, soil borne diseases, dieback |
| Carbendazim | Bavistin 50 DF/ Goldazim 500 SC | Downy mildew, powdery mildew, Botrytis, soilborne diseases |
| Chlorpryfos | Merpan 4 EC | Powdery mildew |
| Chlorothalonil | Bravo 500 SC/ Daconil 75 WP/ Ranco 75 WP/ Ranconil 500 SC | Downy mildew, Botrytis, black spot |
| Chlorothalonil + Metalaxyl | Foliogold 537.5 SC | Botrytis, downy mildew |
| Copper hydroxide | Kocide 101 | Downy mildew, Botrytis, crown gall |
| Cymoxanil + Propineb | Milraz 76 WP | Downy mildew, powdery mildew |
| Cyprodinil + Fludioxonil | Switch 62.5 WG | Botrytis |
| Dazomet | Basamid G | Crown gall, nematodes, soil borne fungi |
| Difenoconazole | Score 250 EC | Downy mildew, Botrytis, Alternaria |
| Dimethomorph + Mancozeb | Acrobat MZ | Downy mildew |
| Dithianon | Delan 500 SC | Downy mildew |
| Dodemorf acetate | Meltatox 40 EC | Powdery mildew |
| Famoxate + Cymoxanil | Equation Pro DF | Downy mildew |
| Fenamidone +Fosetyl-Aluminium | Verita WP | Downy mildew |
| Fenarimol | Rubigan 12 EC | Powdery mildew |
| Fenhexamid | Teldor WG 50 | Botrytis |
| Flusilazole | Nustar 40 EC | Powdery mildew |
| Folpet | Folpan 50WP | Downy mildew |
| Fosethyl –Aluminuim | Fast WP/ Fosotonic 80 WP/ Aliette 80 WP | Downy mildew, Botrytis, Pythium, Phytophthora, |
| Hexaconazole | Anvil 5 SC | Powdery mildew |
| Iminoctadine | Bellkute 30% FL | Powdery mildew |
| Iprodione | Rovral Aquaflo 500/ Ippone 500 SC/ Iprodione 50% SC/ Rovral 250 flow | Botrytis, Alternaria |
| Kresoxim-methyl | Ardent 50 SC | Powdery mildew |
| Kresoxim-methyl | Stroby 50 WG | Powdery mildew, Botrytis |
| Mancozeb | Mancozeb 80 WP/ Sancozeb 80% WP/ Dithane M-45 | Downy mildew, Botrytis, Alternaria, rust, crown gall, Erwinia |
| Manganese + Zineb | Mancozan | Alternaria |

Appendix 1. Contd.

| Active ingredient | Trade name | Target pests |
|---|---|---|
| Metalaxyl +Mancozeb | Ridomil Gold MZ 68 WP/ Victory 72 WP | Pythium, downy mildew, black spot |
| Metalaxyl 25% | Ridomil MZ | Phytophthora, Pythium |
| Metham sodium | Metham sodium | Soil sterilization |
| Methram complex | Polyram DF | Downy mildew, Alternaria |
| Mono & Dipotassium phosphate | Agri-Fos 400 AS | Downy mildew |
| Myclobutanil | Systhane 12 EC | Powdery mildew |
| Oxycarboxin | Plantvax 20 EC | Rust |
| Penconazole | Topas 10 EC | Powdery mildew |
| Pentachloronitrobenzene + Etridiazole | Terrachlor Super X EC | Phytophthora, Pythium, Rhizoctonia, Fusarium blights |
| Polyoxin B | Milpan 10 WP | Downy mildew, PM |
| Polyoxin AL | Polar 50 WG | Powdery mildew, Botrytis |
| Propamocarb | Dorado | Downy mildew |
| Propamocarb + Fosetyl | Previcur Energy SL 840 | Downy mildew |
| Propamocarb –HCL | Previcur N | Downy mildew, Botrytis, Phytophthora, Pythium |
| Propiconazole | Bumper 25 EC/ Tilt 250 EC | Powdery mildew, rust in *Hypericum* |
| Propineb | Antracol 70 WP | Downy mildew, Botrytis and Rhizoctonia |
| Propineb + Iprovalicarb | Melody duo 69 | Downy mildew, Botrytis |
| Propamocarb hydrochloride | Proplant 722 SL | Downy mildew |
| Pyrimethanil | Scala 40 SC | Botrytis |
| Quaternary (Didecyldimethyl Ammonium chloride) | Sporekill | Powdery mildew, Botrytis |
| Spiroxamine | Impulse EC 500 | Powdery mildew |
| Sulphur | Kumulus DF/ Sulphur dust/ Thiovit Jet 80 WP | Powdery mildew, Botrytis, downy mildew |
| Tebuconazole | Orius 250 EW/ Folicur 250 EC/ | Rust, powdery mildew |
| Tetraconazole | Domark 40 EW/ Domark 50 EW | Powdery mildew |
| Thiabendazole | Tecto 500 SC | Botrytis, powdery mildew |
| Thiophanate-Methyl | Topsin M | Botrytis, powdery mildew, Fusarium blights, soil borne diseases, Rhizoctonia |
| Thiram | Thiram 80 WP/ TMTD 98% Satec | Botrytis |
| Tolclofos methyl | Rizolex 50 WP | Fusarium, soil borne diseases, Rhizoctonia, crown gall |
| Tolylfluanide | Euparen M/ Euparen 50 WP | Botrytis, Rhizoctonia |
| Triadimefon | Bayleton 25 WP | Powdery mildew |
| Trifloxystrobin | Flint WG 50 | Powdery mildew, rust |
| Triforine | Saprol 20 EC | Powdery mildew, rust |

Appendix 2. Insecticides/nematicides recommended by PRC for registration since April 2006.

| Active ingredient | Trade name | Target Pests |
|---|---|---|
| Abamectin | Akrimactin 1.8 EC/ Dynamec 1.8 EC/ Spidermec 018EC/ Vertimec/ Abalone 18 EC/ Romectin | Spider mites |
| Acephate | Ace / Orthene 75 SP | Aphids, thrips, caterpillars, whitefly |
| Acetamiprid | Golan 20% SC | Aphids, thrips, leaf minor, flea beetle |
| Acetamiprid | Mospilan 200 SP | Aphids |
| Acrinathrin | Rufast 75 EC | Spider mites, aphids, thrips |
| Alpha-cypermethrin | Fastac 10 EC | Spider mites, aphids, thrips, caterpillars, whitefly |
| Amitraz | Kilitac/ Mitac 20 EC | Spider mites, whitefly |
| Azadrachtin | Achook 0.15 EC | Caterpillars, nematodes |
| Azocyclotin | Peropal 25 WP | Thrips, spider mites |
| *Bacillus thuringiensis* | Turex 50 WP/ Xentari | Caterpillars, whitefly |
| Beta-cyfluthrin | Bulldock 25 EC | Thrips |
| Bifenazate | Floramite 240 SC | Spider mites |
| Bifenthrin | Brigade 25 EC/ Talstar 100 EC | Spider mites, aphids, thrips, caterpillars, whitefly |
| Bromopropylate | Neoron 500 EC | Spider mites |
| Buprofezin | Applaud 40% SC | Whitefly |
| Cadusafos | Rugby 100 ME | Nematodes |
| Carbofuran | Furadan 350 ST | Termites |
| Chlorphenaphyr | Secure 36 SC | Mites, caterpillars, whitefly |
| Chlorpyrifos | Dorpas/ Dursban 4 EC/ Pyrinex 48 EC | Caterpillars |
| Clofentezin | Apollo 50 SC | Spider mites, aphids |
| Cypermethrin | Polytrin C 440 EC/ Sherpa 5% EC | Aphids, spider mites, thrips |
| Cyromazine | Trigard 75 WP | Leaf minor, spider mites |
| Deltamethrin | Decis 25 EC | Aphids, thrips, caterpillars |
| Diafenthiurion | Mercur 500 | Mites, caterpillars, whitefly |
| Diafenthiurion | Pegasus 500 SC | Spider mite, caterpillars, whitefly |
| Diazinon | Diazinon 60 EC/ Diazol 60 EC | Aphids, thrips, caterpillars whitefly, nematodes, termites, cutworms |
| Dicofol | Kelthane 18.5 EC/ Mitigan 18.5 EC | Spider mites |
| Dienochlor | Pentac Aqua 480 | Spider mites |
| Dimethoate | Dimethoate 40 EC | Aphids, thrips |
| Ethoprophos | Mocap 10 GS | Nematodes |
| Fenamiphos | Nemacur 5G | Nematodes |
| Fenazaquin | Magister 200 SC/ Pride 200 SC | Spider mites |
| Fenbutatin oxide | Torque 50 WP | Spider mites |
| Fentin acetate 54% + Maneb 28% | Brestan 60 WP | Nematodes |

Appendix 2. Contd.

| **Active ingredient** | **Trade name** | **Target Pests** |
|---|---|---|
| Flufenoxuron | Cascade 10 DC | Spider mites |
| Hexythiazox | Nissorun 10 EC | Spider mites |
| Imidacloprid | Confidor 200 SL / Gaucho 350 FS | Spider mites, aphids, thrips, caterpillars, whitefly, termites |
| Indoxacarb | Avaunt 300/150 SC | Caterpillars |
| Lambda-cyhalothrin | Karate 17.5 EC / Lambdex 5% EC | Aphids, thrips, caterpillars, whitefly, leaf minor, flea beetle, spider mites, leafhoppers |
| Lufenuron | Match 50 EC | Caterpillars, whitefly |
| Methiocarb | Mesurol 500 SC/ Methiocarb | Aphids, thrips, caterpillars, whitefly, spider mites |
| Methomyl | Methomex 90 SP/ Lannet 90 WS | Aphids, thrips, caterpillars, whitefly |
| Omethoate | Folimat 500 SL | Aphids |
| Oxamyl | Vydate 10 L | Spider mites, aphids, thrips, caterpillars, whitefly, leaf minor |
| Oxymatrin | Oxymetrin 2.4 SL | Spider mites, aphids, thrips, caterpillars, termites, leafhoppers |
| Primicarb | Pirimor 50 DG | Aphids |
| Pyrmidifen | Miteclean 10% SC | Spider mites |
| Profenofos | Selecron 720 EC | Spider mites, thrips |
| Propargite | Omite 57 EC | Spider mites |
| Spinosad | Tracer 480 SC | Thrips, caterpillars |
| Spiromesifen | Oberon SC 240 | Spider mites |
| Tau fluvalinate 24% | Mavrik AF | Spider mites, aphids, thrips, leaf minor |
| Tebufenpyrad | Oscar 20 SC -200 EC | Spider mites |
| Tetradifon | Tedion V-18 EC | Spider mites, thrips |
| Thiacloprid | Calypso SC 480 | Spider mites, aphids, thrips |
| Thiamethoxam | Actara 25 WG | Aphids, caterpillars, whitefly |
| Thiocyclam | Evisect S | Aphids, thrips, caterpillars, whitefly, leaf minor |
| Thiophanate-Methyl | Topsin M | Nematodes |

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# Disease and Insect Pests of Aromatic, Medicinal and Non-edible Industrial Oil Bearing Plants in Ethiopia

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## Introduction

Ethiopia is endowed with rich flora due to its physical and climatic diversity where about 12% of the higher plants are endemic and more than 14% of these are aromatic and medicinal plants (Fasil, 2001). Due to their natural photosynthetic and metabolic pathways, plants can serve as source of either primary (fats, lipids, proteins, amino acids, etc.) or secondary (alkaloids, terpenoids, essential oils, anthracene, etc.) metabolic products that can be used for variety of purposes. Apart from food and feed sources, such biological resources can be utilized as pure products, mixtures, isolation and synthesis of prototypes. The resource bases for aromatic, medicinal, and other industrial oil bearing plants can be categorized as:

- essential oils and oleoresins (grasses, geranium, jasmine, citrus, vetiver, sandalwood, mint oils, cedar wood, nutmeg and clove),
- plant saps and extracts (gums, resins, other vegetable saps and extracts),
- raw plant materials (medicinal and aromatic plants, seaweed and algae),
- vegetable oils, fats and waxes (castor oil, coconut oil, peanut oil, sweet almond oil, cocoa, vernonia oil, curcas oil, rap seed oil, olive oil),
- natural colors (indigo, carmine, curcuma/turmeric, marigold and henna),
- tannins (acacia, vegetable, ariticum), and
- other medicinal ingredients (alkaloids, saponins, flavonoids, terpenoids, glycosides, etc.)

These groups of plants play a significant role in the foreign market of Ethiopia (CAE, 2007). The major plant species in this group include *Acacia* spp., *Aframonum* sp., *Aloe* sp., aromatic grasses (*Cymbopogon martini*, *C. citratus* and *C. winteranus*), mints (*Mentha arvensis, M. piperata, M. spikata* and *M.*

*longfolia*), geranium (*Pelargonium graveolens*), eucalyptuses (*Eucalyptus globules* and *E. citridora),* pyrethrum (*Chrysanthemum cinerariaefolium),* "koso" (*Hagenia abyssinica*), "endod" (*Phytolacca dodecandra),* vernonia (*Vernonia galamensis*), *Nigella sativa*, physic nut (*Jatropha curcas*), castor bean (*Ricinus cummunis*), and fenugreek (*Trigonella foenum-graecum*).

Natural products derived from these plants can be used in various ways. Among the areas of their applications, include pharmaceutical, cosmetic, food and beverage, paint, paper, textile, soap, tobacco, and agrochemical industries. Despite their importance, research on these plants was not given adequate attention, although some collection, adaptation, chemical extraction, and agronomic studies on a few of these plants started in 1950's by different institutions in the country. Eventually a small-scale oil extraction laboratory was established by the then National Chemical Corporation in 1960s at Wendo Genet, which was followed by conservation of some important exotic and local plant species. Later the Ministry of Trade and Industry had launched essential oils production project and established essential oils research main laboratory for promotion of export and import substitution. Then after, different organizations such as SIDA/SAREC, UNIDO, FAO, IBC, ESTCE/ESTA supported the research and development of the sector. Recently, however, the Essential Oils Research Center (EORC) of the EIAR is undertaking research on some of these plants (EIAR, 2006). Almost all of the research programs are on propagation and agronomic management with the intention to address the importance of promoting aromatic and medicinal plants in the growing world market, while none on their pest problems were received adequate attention.

Like any other plants of economic importance, aromatic, medicinal, and non-edible oil-bearing plants are attacked by a number of disease and insect pests as it can be seen from the scanty information scattered over different sources. The purpose of this paper is to collate the scattered information, analyze gaps and challenges, and indicate future research directions.

# Research findings

## Diseases recorded

The diseases recorded on aromatic and medicinal plants in Ethiopia are shown in Table 1. Ten pathogens were recorded as minor diseases of *Acacia* spp. by Stewart and Dagnachew (1967). On *Aframonum* sp. only rust caused by *Puccinia aframomi* was recorded as a minor disease. A hyperparasite fungus called *Eudarluca caricis* was also found on the rust causing fungus (*P. aframomi*) on the same host plant. Eight pathogens were known to cause

disease on *Aloe* sp. Blight caused by *Ramularia* sp. was reported to be a serious disease of pyrethrum especially during the rainy periods. The October and November rains are reported to cause severe damage to *Chrysanthemum* flowers at Holetta. Bazezew et al. (n. d.) reported that root knot nematode (*Melodogyne halpa*), young flower bud infections (*Ramularia*, *Bullunensis*, *Alternaria*, *Aschochyta* spp), root rot and wilt (*Fusarium*, *Rhizoctonia*, *Sclerotinia* and *Aschochyta* spp.) are major diseases of pyrethrum.

Several pathogens cause diseases on aromatic grasses (*Cymbopogon* spp.) in Ethiopia (Stewart and Dagnachew, 1967; Tesfaye, 2005). Rust caused by *Puccinia nakanishikii* was reported to be a serious disease on grasses. Field observations on three grass species indicated that *C. winteranus* was highly tolerant, *C. citratus* was moderately tolerant, while *C. martini* was highly susceptible to rust infection (Getinet, pers. com.). However, this observations need to be confirmed through further studies. On Eucalyptus, 10 pathogens causing different diseases (canker, blight, spot, mildew, and lesions) were recorded in Ethiopia (Table 1). Stewart and Dagnachew (1967) and Awgichew (1982) reported several types of leaf spot diseases of *Eucalyptus* spp. These include *Cercoseptoria, Pestalotiopsis* spp. and *Phaeoseptoria eucalypty. Dothiorella* sp. and *Fracchiaea heterogena* were also reported to cause twig and stem canker, while *Stomiopeltis* sp. caused twig blight of *Eucalyptus*. However, all of these diseases were reported to be of minor importance. Geranium was attacked by *Fusarium* and *Uromyces* spp. (Stewart and Dagnachew, 1967; Tesfaye, 2005). Tesfaye (2005) reported that a soil-borne disease caused by *Fusarium* sp. was responsible for wilt, which inflicted stand losses. Rust caused by *Uromyces geranii* was also reported to attack geranium. Both rust and wilt were considered to be of medium importance. According to Stewart and Dagnachew (1967), powdery mildew is a major disease in physic nut **(***Jatropha curcas*). Studies conducted in 2006 indicated that the incidence and severity of powdery mildew (*Oidium* sp.) were high in Wello, Wollaita Sodo, and Goffa (Mekuria, pers. com.). Severe infections were reported on leaf, flower, and green cherries in many places. The disease was found to cause premature defoliation of leaves and shrinking of cherries that may result into serious loss in physic nut yield. In addition, *Pencillium* and *Aspargillu*s spp. were found in association with seeds collected from different regions in the country. Among the diseases recorded on *Mentha* spp. rust caused by *Puccinia menthae* was reported to be of major importance, while leaf spot caused by *Cercospora menthicila* was minor (Stewart and Dagnachew, 1967). Among all the mints, peppermint was the most affected by rust (Tesfaye, 2005), although the degree of severity varied with locations.

Table 1. Diseases recorded on some aromatic and medicinal plants.

| Host plant | Disease/part infected | Pathogen | Status | Ref. |
|---|---|---|---|---|
| *Acacia* spp. | Rust | *Aecidium immursum* | minor | 17 |
| *Acacia* spp. | Rust | *A. torquens* | minor | 17 |
| *Acacia* spp. | On trunk | *Stereum hirsutum* | minor | 17 |
| *Acacia* spp. | On trunk | *Fomes lucidus* | minor | 17 |
| *Acacia* spp. | Rust | *Uromyces schweinfurthil* | minor | 17 |
| *Acacia* spp. | Rust | *Ravenelia volkensii* | minor | 17 |
| *Acacia* spp. | On trunk | *Lenzitus palisotii* | minor | 17 |
| *Acacia* spp. | On wood | *Hexagonia klotzschii* | minor | 17 |
| *Acacia* spp. | On dead trunk | *Polystictus sanquineus* | minor | 17 |
| *Acacia* spp. | On branchs | *Trametes torrida* | minor | 17 |
| *Aframonum* sp. | Rust | *Puccinia aframomi* | minor | 12077a |
| *Aloe* sp. | Anthracnose | *Colltotrichum aloe* | minor | 17 |
| *Aloe* sp. | Lesions | *Discella aloetica* | minor | 17 |
| *Aloe* sp. | On leaves | *Dothidea aloicola* | minor | 17 |
| *Aloe* sp. | On leaves | *Macrophoma aloes* | minor | 17 |
| *Aloe* sp. | On leaves | *Montagnella hanburyana* | minor | 17 |
| *Aloe* sp. | On leaves | *Placoasterella rehmi* | minor | 17 |
| *Aloe* sp. | On trunk | *Polystictus sanguineus* | minor | 17 |
| *Aloe* sp. | Rust | *Uromyces aloes* | minor | 120778 |
| *Artemisia* sp. | Rust | *Puccinia absinthii* | minor | 17 |
| *Chrysanthemum cinerariaefolium* | Blight | *Alternaria sp.* | ? | 2, 17 |
| *C. cinerariaefolium* | Blight | *Aschochyta sp.* | ? | 2, 17 |
| *C. cinerariaefolium* | Blight | *Bullunensis sp.* | ? | 2, 17 |
| *C. cinerariaefolium* | Wilt | *Fusarium oxysporum* | minor | 2, 17 |
| *C. cinerariaefolium* | Blight | *Ramularia sp.* | major | 2, 17 |
| *C. cinerariaefolium* | Root rot | *Rhizoctonia sp.* | ? | 2, 17 |
| *C. cinerariaefolium* | Root rot | *Sclerotinia sp.* | ? | 2, 17 |
| *Cymbopogon citratus* | Rust | *Puccinia nakanishikii* | major | 17, 20 |
| *C. martini* | Rust | *P. nakanishikii* | moderate | 17, 20 |
| *C. winteranus* | Rust | *P. nakanishikii* | moderate | 17, 20 |
| *Eucalyptusglobulus* | Gray mold | *Botrytis cinerea* | ? | 116678 |
| *E. globulus* | On leaf | *Glomerella cingulata* | ? | 125159 |
| *E. globulus* | On leaf | *Mycosphaerella molleriana* | ? | 17 |
| *E. globulus* | Powdery mildew | *Oidium* sp. | ? | 17 |
| *Eucalyptus* spp. | Leaf spot | *Cercoseptoria* sp. | minor | 17 |
| *Eucalyptus* spp | Twig canker | *Dothiiorella* sp. | minor | 1, 17 |
| *Eucalyptus* spp | Stem canker | *Fracchiaea heterogena* | minor | 1, 17 |
| *Eucalyptus* spp | Leaf spot | *Pestalotiopsis sp.* | minor | 1, 17 |
| *Eucalyptus* spp | Leaf spot | *Phaeoseptoria eucalyptus* | minor | 1, 17 |
| *Eucalyptus* spp | Twig blight | *Stomiopeltis sp.* | minor | 1, 17 |
| *Gloriosa* sp. | On leaves | *Acrothecium lunatum* | minor | 17 |
| *Gloriosa* sp | Leaf blight | *Cercospora gloriosae* | minor | 1, 17 |
| *Hagenia abyssinica* | Iinflorescence | *Coniothyrium abyssinicum* | minor | 17 |

Table 1. Cont.

| Host plant | Disease/part infected | Pathogen | Status | Ref. |
|---|---|---|---|---|
| *H. abyssinica* | On leaves | *Phleospora hageniae* | minor | 17 |
| *H. abyssinica* | On leaves | *Stigmatea hageniae* | minor | 17 |
| *Jatropha curcas* | Mould | *Asperigillus* sp. | minor | 17, M |
| *J. curcas* | Powdery mildew | *Oidium sp.* | major | 17 |
| *J. curcas* | Mould | *Penicillium sp.* | minor | 17, M |
| *Lepidium sativum* | White rust | *Albugo candida* | minor | 116665 |
| *L. sativum* | Leaf spot | *Alternaria brassicae* | minor | 120762 |
| *Mentha* sp. (pepper mints) | Leaf spot | *Cercospora menthicila* | minor | 17, 19 |
| *Mentha* sp. | Rust | *Puccinia menthae* | major | 17, 20 |
| *Nigella sativa* | Leaf spot | *Cercospora nigellae* | moderate | 116674 |
| *Ocimum basilicum* | Downy mildew | *Perenospora lamii* | minor | 1, 116658 |
| *Ocimum suave* | Rust | *Puccinia ocimi* | minor | 116600 |
| *Osyris abyssinica* | Sooty mould | *Meliola ostyridis* | ? | 1, 17 |
| *Osyris* sp. | Black mildew | *Meliola polytricha* | minor | 88415 |
| *Pelargonium graveolens* | Wilt | *Fusarium* sp. | moderate | 20 |
| *P. graveolens* (Geranium) | Rust | *Uromyces geranii* | moderate | 17 |
| *Pelargonium* sp. | Rust | *Puccinia pelargonii-zonalis* | moderate | 88596 |
| *Pelargonium* sp. | Leaf spot | *Septoria geranii* | minor | 88545 |
| *Phytolacca dodecandra* | Leaf spot | *Cercospora phytolaccae* | minor | 17 |
| *Prunus africana* | Trunk infection | *Phomopsis padina* | ? | 1, 17 |
| *Ricinus communis* | Leaf spot | *Alternaria ricini* | minor | 4, 17 |
| *R. communis* | Leaf spot | *Asochyt ricinella* | minor | 4, 17 |
| *R. communis* | Grey mould | *Botryotinia ricini* | minor | 4, 17 |
| *R. communis* | Leaf spot | *Cecospora ricinella* | minor | 17 |
| *R. communis* | Wilt | *Fusarium spp* | moderate | 4, 17 |
| *R. communis* | Rust | *Melampsora ricini* | major | 4, 17 |
| *R. communis* | On leaf | *Phyllosticta ricini* | minor | 88307a |
| *R. communis* | Downy mildew | *Phytophthora parasitica* | minor | 17 |
| *R. communis* | Bacterial spot | *Xanthomonas ricini* | minor | 17 |
| *Ruta* sp. | Stem lesion | *Alternaria tenuissima* | minor | 125167 |
| *Trigonella foenum-graecum* | Leaf spot | *Cercospora traversiana* | moderate | 17 |
| *T.graecum* | Powdery mildew | *Oidium* sp. | major | 17 |
| *T. graecum* | Rust | *Uromyces anthyllidis* | minor | 17 |
| *Vernonia galamensis* | Leaf spot | *Alternaria* sp | minor | 17, 19 |
| *V. galamensis* | Powdery mildew | *Blumeria sp* | minor | 17, 19 |
| *V. galamensis* | Wilt/damping off | *Fusarium* spp | minor | 17, 19 |
| *V. galamensis* | Leaf spot | *Phoma sp* | minor | 17, 19 |
| *V. galamensis* | Rust | *Puccinia punctiformis* | major | 17, 19 |
| *V. galamensis* | Damping off | *Rhizoctonia solani* | minor | 17, 19 |
| *V. galamensis* | Leaf blight | Unidentified bacteria | minor | 17 |
| *V. galamensis* | Powdery mildew | *Erysiphe* sp. | minor | 19 |

M = Mekuria pers. observation.

Stewart and Dagnachew (1967) recorded a minor leaf spot disease caused by *Cercospora phytolaccae* on endod. Getaneh (2005) listed five parasitic nematodes namely *Aphelenchus avenae*, *Aphelenchoides*, *Helicotylenchus*, *Rotylenchus* and *Tylenchorhynchus* spp. and a fungus (*Fusarium oxysporum*). The pathogens were known to attack many other plant species that are found in association with endod. The result need to be confirmed with thorough pathogenicity test under control conditions in order to list them as endod pathogen. These pathogens were presumed to cause wilting and death of endod plants in the study area. Traditional castor bean production in the country is threatened by several pathogenic organisms such as rust (*Melampsora ricini*), leaf spot (*Ascochyta ricinella*), leaf blight (*Alternaria ricini*), inflorescence blight (*Botryotinia ricini*) and wilt (*Fusarium* sp.). Only the former disease was considered a major limiting factor due to its severe defoliation in large scale production of castor bean. On fenugreek (*Trigonella foenum-graecum*) three pathogens were recorded among which *Oidium* sp. the most important followed by *Cercospora traversiana* (Table 1). Rust was recorded as a minor disease. Awgechew (1982) reported the occurrence of sooty mould (*Meliola ostyridis*) on sandalwood (*Osyris abyssinica*), trunk infection (*Phomopsis padina*) of 'tikur-inchet' (*Prunus africana*) and downy mildew (*Perenospora lamii*) disease of basil (*Ocimum basilicum*).

## Losses caused by diseases

No systematic loss assessment study was carried out for any of the diseases reported on the different plants concerned in this review. The status of the diseases was simply judged on visual observations of their occurrence and severity in different locations and seasons. The only information found was from a study conducted recently which indicated that losses of oil content of *Cymbopogon martini* reached up to 5, 22 and 54% as rust damage increased to 25, 25-50 and $\geq$ 50% severity, respectively (Mekuria, unpublished data).

## Disease control

Regarding control of diseases, the suggestions made include use of tolerant/resistant clones, crop rotation, spraying of pyrethrum and soap solution to control pyrethrum diseases and dipping of pyrethrum splits into a fungicide, Ridomil, to reduce disease spread (Bazezew *et al*., n. d.). Generally, however, management strategies against diseases in these plants could be developed by considering experiences from other and similar plant diseases that were well studied in the country and elsewhere. Obvious differences in wilting and dead plants were reported to be observed among endod types studied at Gemadro plantation, Illubabor. The incidence was 0% for E-44 and Metti types, and 27.7% for the Getiba type (Getaneh, 2005). Hence, use of resistant varieties and avoidance of infected fields can reduce diseases of endod. Dagatchew (1966)

reported that late maturing castor bean varieties were more tolerant to rust infection than dwarf and early maturing types.

### Insect pests and mites recorded

Insect pests recorded on these groups of plants in Ethiopia are presented in Table 2. On vernonia, important pests were vernonia worm (*Indent* sp.) followed by helmet bug (*Captosoma* sp.). The major pest recorded on eucalyptus was aphid. Tesfaye and Sileshi (2002) reported that helmet bug alone inflicted over 80% damage to endod at Yaballo. On endod (*Phytolacca dodecandra*), two species of fruit flies namely *Gitona pauliani* and *G. ethiopica* were the major insect pests, the former was reported to be more important. Surveys conducted at different endod growing areas of the country showed that the mean percentage infested branches due to these pests ranged from 10-75%. Stem samples collected from Showa, Sidama and Arsi showed severe (> 50%), from Dessie moderate (25- 50%) and from Hararghe and Wollega slight (< 25%) infestations by the flies (Mekonen, 2002). Sciarid flies, flower thrips and white fly were reported to be important pests of *Pelargonium graveolens*. On *Ruta* sp. heavy white fly infestations were observed in Addis Ababa (Abraham Tadesse, pers. observ.). . A leaf miner and white wooly aphid were observed to severely infest physic nut **(***Jatropha curcas*) at Tibila and Upper Awash (Mekuria, pers. com.)

## Basic studies

Mekonen (2002) studied the biology of the two *Gitona* spp. attacking endod and found that eggs of *G. pauliani* and *G. ethiopica* took 4.1 and 6.2 days to hatch, respectively. The larvae of both species were whitish in color upon hatching and become yellowish when fully grown. The average larval period was 29.6 and 49.5 days for *G. pauliani* and *G. ethiopica*, respectively. Pupae of both species were light brown soon after pupation, and later became dark brown. The pupation periods of *G. pauliani* and *G. ethiopica* were 14.6 and 14.8 days, respectively. The longevities of the former and later insects were 13.9 and 21.9 days, respectively. *Gitona ethiopica* laid an average of 20.7 eggs within 3.8 days, while *G. pauliani* laid 30.8 eggs within 11.3 days.

### Insect control

Control measures against insect pests of this group of plants were not studied except a few observations on endod, pyrethrum and vernonia. The use of resistant endod varieties has been suggested as one of the most promising means to control *Gitona* spp. (Shibru, 1994). So far, 65 different varieties of endod were evaluated for their resistance to insect pests and other desirable characteristics (Legesse et al., 1987). Of the 11 promising varieties selected, three have shown potential resistance to the pests (Legesse, 1995).

Table 2: Insect pests recorded on some aromatic and medicinal plants.

| Host plant | Common name | Pest scientific name | Status | Ref. |
|---|---|---|---|---|
| *Vernonia galemensis* | Apid | *Aphis gossypi* | minor | 19 |
| *V. galemensis* | Blister beetle | *Mylabris* sp. | minor | 19 |
| *V. galemensis* | Cluster bugs | *Agronoscellis pubescens* | minor | 19 |
| *V. galemensis* | Epilachna beetle | *Epilachna* sp. | minor | 19 |
| *V. galemensis* | Green grasshopper | *Orinthacris* sp. | minor | 19 |
| *V. galemensis* | Green stick bug | *Nazara virdula* | minor | 19 |
| *V. galemensis* | Harlequin bug | *Bagrada* sp. | minor | 19 |
| *V. galemensis* | Helmet bug | *Captosoma* sp. | medium | 19 |
| *V. galemensis* | Leaf miner | *Liriomyza* sp. | minor | 19 |
| *V. galemensis* | Lygaeus bug | *Lygus* sp. | minor | 19 |
| *V. galemensis* | Spiny boll worm | *Earias biplaga* | minor | 19 |
| *V. galemensis* | Striped blister | *Epileauta* sp. | minor | 19 |
| *V. galemensis* | Vernonia worm | *Indent* sp. | major | 19 |
| *Eucalyptus globulus* | termites | *Odontotermes anceps* | - | 9 |
| *Eucalyptus* spp. | Aphid | *Aphis* sp.*?* | major | 9 |
| *Chrysanthemum* sp. | Thrips | *Thrips nigropilosus* | minor | 21 |
| *C. cinerariaefolium* | Onion thrips | *Thrips tabaci* | minor | 21 |
| *C. cinerariaefolium* | Aphid | *Myzus persicae* | minor | 21 |
| *C. cinerariaefolium* | Aphid | *Dactynotus compositae* | minor | 21 |
| *Phytolacca dodecandra* | Fruit fly | *Gitona pauliani* | major | 11,14, 18 |
| *P. dodecandra* | Fruit fly | *Gitona ethiopica* | major | 11,14,18 |
| *Pelargonium graveolens* | Aphid | *Aphis gossypii* | minor | 5 |
| *P. graveolens* | Sciaride flies | *Bradysia* spp. | major | 5 |
| *P. graveolens* | Flower thrips | *Frankliiniella* sp. | medium | 5 |
| *P. graveolens* | White fly | *Trialeurodes vaporarium* | medium | 5 |
| *Foeniculum vulgarae* | Leaf minor | *Icerya purchasi* | minor | 21 |
| *Ruta graveolens* | Leaf minor | *Icerya purchasi* | minor | 21 |
| *R. graveolens* | Red scale | *Aonidiella orientalis* | minor | 21 |
| *Ruta* sp. | whitefly | - | major | A |
| *Ricinus communis* | - | *Eurystylus kivuensis* | - | 9 |
| *R. communis* | - | *Pitarcha* sp. | | 9 |
| *R. communis* | - | *Thalassodes digressa* | - | 9 |
| *R. communis* | - | *Xyleutes capensis* | - | 9 |

Table 2: Cont.

| Host plant | Common name | Pest scientific name | Status | Ref. |
|---|---|---|---|---|
| *Aloe* megalacantha | - | *Dupliachionaspis* sp. | - | 9 |
| *Aloe* megalacantha | - | *Drosophilla busckii* | - | 9 |
| *Apium graveolens* | | *Dysaphis foeniculus* | minor | 21 |
| *A. graveolens* | | *Taylorilygus pallidulus* | minor | 21 |
| *Geranium* sp. | Greenhouse white fly | *Trialeurodes vaporariorum* | minor | 21 |
| *Foeniculum vulgare* | Cottony cushion | *Icerya purchasi* | - | 21 |
| | Carrot aphid | *Cavariella aegopodii* | - | 21 |
| *Ocium* spp. | Tortoise beetle | *Aspidomorha quadrimaculata* | - | 21 |
| | Noug flea beetle | *Decaria abdominalis* | - | 21 |
| *Cichorium intybus* | Cutworm | *Agrotis segetum* | - | 21 |
| *Anethum gravaolens* | Carrot aphid | *Cavariella aegopodii* | - | 21 |
| | Fennel aphid | *Dysaphs foeniculus* | - | 21 |
| *Petroselinus crispum* | Carrot aphid | *Cavariella aegopodii* | - | 21 |

A=Abraham Tadesse, personal observation.
- = not known

In addition, some chemical insecticides such as Dipterex, Disyston, Gausathion and Lebaycid were tested against *Gitona* spp. and a satisfactory control was obtained when Lebaycid was sprayed at the rate of 0.1-0.2 % on transplanted cuttings (Lugt, 1981; Legesse et al., 1987). *T. nigropilosus*, *M. persicae* and mites on pyrethrum can effectively be controlled by applying Thiodan 35 % EC at the rate of 1 l/ha in 400 l of water or metasystox at the same rate (Bazezew *et al*., n.d.). As a potential biological control agent, *Euplectus laphygmae* (Hymenoptera: Eulophidae) was found to be larval parasitoid of vernonia worm with an average parasitism rates of 14.2 and 26.2% at Alemaya and Babile, respectively (Sileshi, 1998).

## Gap analysis

Disease and insect pests were not well studied in this group of plant species. Except some scanty records encountered on the identity of pathogens and insects, no research information was found on other aspects of pest problems. Many plants were not covered in the pest surveys conducted, and for those studied only little information was obtained on their distribution, occurrence and the degree of infestation. Moreover, losses were not quantified; and hence, it is difficult to understand the importance of pests on this group of plants. Some control measures were suggested for a few diseases and insect pests which were not supported by research data. Generally, no adequate and organized information is available on disease and insect pest problems of these

plant species as research started very recently. Therefore, there is a very wide research gap to be filled.

# Conclusion and recommendations

Disease and insect pests are important on aromatic, medicinal, and non-edible oil-bearing plants. Although their economic importance has not been established, many disease causing pathogens and insect pests have been recorded. Some plants may host over a dozen of pathogens and insects, while others bear a few. The reported status of different pests does not seem to be very convincing as very few pathogens and/or insects have been recorded as major on only very few plant species. In general, the information available is incomplete. Therefore, it is suggested that future research should include the following:

- Survey and identification of disease and insect pests in major growing areas of these plants
- Study on the biology, losses, epidemiology/population dynamics of major pests and diseases
- Develop sound management strategy for disease and insect problems that may include and/or combine cultural, biological, varietals and/or chemical methods (IPM)
- Establish national pest database for this group of plants
- Consider those many other plant species that are found in the country falling under aromatic and medicinal plants, which need due attention in the future.

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# Review of Diseases and Insect Pests Recorded on Tree Species in Forests of Ethiopia

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## Introduction

### Forest and its importance

Wood plays a major role in meeting more than 85% of the energy requirements of Ethiopia (EFAP, 1994). Mostly, this wood comes from the natural forests and woodlands. For this reason, natural forest resources are diminishing rapidly. Estimates indicate that the natural forest cover has declined from 40 to 2.4% in the 1990's (Davidson, 1988, Anon., 1994). Wood demand increases with the increasing population growth and, hence, the current annual rate of forest exploitation is much higher than the annual replacement, both in terms of area and yield. If this trend continues, the remaining natural forests will not remain for long and it may not be possible to meet the increasing demand for wood products. To overcome this problem, exotic tree planting was commenced and has been practiced for many years in different parts of Ethiopia.

Currently, fast growing exotic species including *Eucalyptus globulus, E. camaldulensis, E. saligna, E. grandis,* and *E. citriodora* are widely planted in different parts of the country (Negash, 1997, Persson 1995). *Cupressus lusitanica, Pinus patula, Grevillea robusta, Acacia mearnsii* and *A. decurrens* are among the other widely planted genera both in plantations and around homesteads. Plantations of these exotic species cover a total area of about 200 000 ha (Anon., 1994, Vercoe, 1995). This figure includes only the area of the plantations in the national forest priority areas, pre-urban plantations and community woodlots, without including trees planted around homesteads and farmlands.

The woody vegetation resources of Ethiopia are categorized as high forest, woodlands, bush lands and on farm trees. The high forests cover about 2.3, woodland 5, bush land 20 and plantation 0.2 million hectares. The on-farm area

coverage of the trees is not well known (EFAP, 1994). The benefits to be taped from these resources are diverse ranging form source of household energy, raw material for construction, furniture, edible fruits, medicinal plant, and forage for animals.

### Importance of forest disease and insect pests

Studies conducted worldwide indicted that pathogens play significant role in modifying or altering the dynamics of natural forest communities. A number of such reports indicated that diseases have impact on species distribution, forest structure and composition, succession, and biodiversity. Pathogens influence the survival of regenerating seedlings and hence influence the occurrence and abundance of plant species. Tree pathogens also significantly influence in delimiting ecological niches (including temperature, topography, aspect, moisture regime) where the susceptible and resistant varieties of tree species better adapt. For example, *Cryphnectria parasitica*, a pathogen of American chestnut, eliminated chestnut trees from the forest community and caused change in species composition and structure. Similarly, insect pests are also among the major constraints in the successful establishment of plantation forest (Abdurahman, 1992). Some insects pests attack the root system and cause wilting and death; others cause defoliation or ring bark the stem there by causing poor growth or death of trees, while some other insects serve as vectors transmitting tree diseases.

In Ethiopia, many indigenous and exotic trees species die at different stage of maturity for various reasons. However, no study has been conducted to investigate the cause of this death and it has been usually arbitrarily associated with poor species site matching and inadequate tending practices, adverse climatic conditions including moisture stress, drought, and shallow soil and over maturity. The role of biotic factors in causing tree death, on the other hand, has been underestimated or poorly understood and has not received adequate attention.

The scanty information available on tree diseases is not easily accessible. This review compiles available information on tree diseasess and insect pests, identifies information gaps that research in future should focus on, and the need for building capacity in terms of both facility and human resources.

## Research findings

### Records of important tree diseases

Adequate information is not available on the damage pathogens cause to trees both in natural and plantation forests of Ethiopia. However, a few records of

tree diseases can be found in forms of field visit reports and some are in the form of published articles (Table 1).

Table 1. Diseases recorded on some exotic and indigenous tree species.

| Common name | Scientific name | Tree species attacked | Reference |
|---|---|---|---|
| Dothistroma needle blight | *Dothistroma pinii* | *Pinus radiata* | 50 |
| Leaf spot | *Phaoeophelospora epicocoides* | *Eucalyptus saligna, E. globulus* | 33, 89 |
| Mycisphaerela leaf disease | *Mycosphaerella nubilosa, M. marksii, M. parva* | *Eucalyptus globulus* | 11, 48 |
| Heart rot and decay | *Antrodia juniperina* | *Juniperus exelsa/ procera* | 72 |
| Heart rot and decay | *Hymenochaete ochromarginata, Phellinus ferruginosus, Trametes socotrana, Asterostroma medium, Cystidiodontia isabellina Dichostereum kenyense* | *Hagenia abyssinica* | 71 |
| Root rot | *Armillaria mellea, A. fuscipes* | *Pinus patula, Acacia abyssinica, Juniperus exelsa, Cordia alliodora, Cederla odorata* | 36, 47, 65, 74 |
| Pink disease | *Erythricium salmonicolor* | *Eucalyptus camaldulensis* | 48, 49 |
| Coniothyrium stem canker | *Conithyrium zuluense* | *Eucalyptus camaldulensis* | 10, 48 |
| Botryosphaereia stem canker | *Botryosphaeria parva, Botryosphaeria* spp. | *E. globulus, E. saligna, E. grandis, E. citrodora, Pinus patula* | 1, 2, 12, 48 |
| Diplodia stem canker | *Diplodia pinea* | *Pinus patula* | 9, 48 |
| Cytospora canker | *Cytospora abyssinica, Cytospora nitshckii* | *Eucalyptus saligna* | 48 |
| Seed borne fungi | *Cerospora* sp., *Phoma* sp., *Guignardia* sp., *Ulocladium botry, U. chartarum, Pestalotiopsis sp., phomopsis viticola, fusarium oxysporum, B.parva,Diplodia rosulata* | *Podocarpus falcatus, Prunus africana, Pinus patula* | 1, 9 |

## Basic studies on forest tree diseases

Some studies have been carried out on the prevalence of tree diseases and losses they cause in forests. Mengistu (1991) indicated that root rot, wood rot, foliage disease, dieback and damping off were observed in different instances. Dieback of *Cupressus*, *Eucalyptus* and *Acacia* species as well as foliage diseases such as leaf spot, powdery mildew and tar spots were reported to be common on both exotic and indigenous trees with unthrifty growth.

### Needle blight

Dothistroma needle blight caused by *Dothistroma pinii* (*Dothistroma septospora*) is a serious disease in many countries where *Pinus radiata* is grown. The occurrence of dothistroma needle blight was reported on *Pinus radiata* around Addis Ababa (Gibson 1972), but no detail information is available. In some African countries, the severe defoliation caused by *Dothistroma* needle blight had led to abandonment or restriction of planting the fast growing *P. radiata* and in most cases it has been substituted with a slightly slow growing *Pinus patula* (Gibson, 1972; Ivory, 1968; Lee, 1970; Ciesla, et al., 1995; Lundquist and Roux, 1984).

### Foliage disease

The prevalence of *Pseudocerospora eucalyptorum,* the causal agent for *Eucalyptus* leaf spot has been recorded on a herb in Worota, North Ethiopia (Crous, et al., 1989). The specimen of *Kirramyces epicocoides* (syn = *Phaeoseptoria eucalypti*), which is now renamed as *Phaoeophleospra epicocoides* was collected from *Eucalyptus saligna* and *E. globulus* at Gora and Gumuro, southwest Ethiopia (Walker et al., 1992). *Kirramyces epicocoides* causes discrete leaf spot on several *Eucalyptus* species in other countries (Crous, et al., 1989; Walker et al., 1992), however, its status in Ethiopia is not known.

Mycosphaerella leaf diseases (MLD) were reported to be associated with juvenile foliage of *Eucalyptus globulus* (Gezahgne et al., 2003; Alemu et al., 2006). Symptoms of these leaf diseases were recorded from samples obtained from Wondo Genet, Hossana, Endibir, Bedele, Menagesha, Holetta and Addis Alem. Shoot dieback and leaf blotch are the common symptoms of MLD. It causes premature defoliation, retarded growth and leads to the abandonment of planting susceptible species. In several cases, nearly 100% of the juvenile leaves and leaf surfaces were affected by MLD.

In the effort made to determine the fungi involved in causing MLD, three different *Mycosphaerella* species namely *M. nubilosa, M. marksii* and *M. parva* were identified from *Eucalyptus globulus* trees in different parts of Ethiopia

(Alemu et al., 2006). *M. marksii* was isolated only from leaf samples colleted near Hossana. The association of the fungus with *Eucalyptus* species other than *E. globulus* and the importance of *M. marksii* in causing leaf blotch on *Eucalyptus* species under Ethiopian conditions need to be investigated further. *Mycosphaerella parva* was found on leaf samples obtained from Addis Alem, Endibir and Hossana. Ethiopia is the third country to report the occurrence of M. p*arva* (Alemu et al., 2006). The occurrence of this species at different localities support that the fungus is important and might play significant role in MLD out break in Ethiopia.

*Mycosphaerella* leaf disease caused by *Mycosphaerella nubilosa* was found around Endibir, Holetta, Hossana and Bedele (Alemu et al., 2006). This species commonly affects juvenile leaves of *E. globulus*. *M. nubilosa* is a destructive pathogen on *E. globulus* and *E. nitens* in several countries. In South Africa, it causes severe damage to *E. globulus* and led to abandonment of planting the tree species (Lundquist and Purnell 1987). Hence, due attention should be given to *M. nubilosa* in Ethiopia.

## Heart rot and decay

The occurrence of *Antrodia juniperina* on native tree species, *Juniperus exelsa/ procera,* has been reported. *A. juniperin* is reported to be parasitic and saprophytic on stems of *J. exelsa*. This fungus causes heart rot and necrosis of the butt (Niemela and Ryvarden, 1975).

Decay fungi were recorded in natural stands of *Hagenia abyssinica* (Niemela et al., 1998)**.** One of the fungi collected from living trunks and stumps was *Hymenochaete ochromarginata.* This fungus is considered to be the main cause of decay on living *Hagenia* trees. Wood-rot fungi including *Phellinus ferruginosus* and *Trametes socotrana* were also collected from fallen branches and stems of *Hagenia*. The role of these organisms in inciting disease on *Hagenia* was not well established. A number of *Corticioid* fungi such as *Asterostroma medium*, *Cystidiodontia isabellina* and *Dichostereum kenyense* were also recorded on *H. abyssinica* (Niemela et al., 1998). However, no detailed information is available on the importance of these fungi.

## Root rot

The occurrence of *Armillaria* spp. on pine trees (Mengistu 1992) and *A. mellea* in *Coffea arabica* plantations (Eshetu et al. 2000) have been reported. *Armillaria* spp. was reported to be found on recently cleared and planted sites, and where shade trees have been removed. Dagne (1998) reported that Armillaria root rot is found associated with *Grevillea robusta*, one of the multi-purpose trees species planted around Wondo Genet. Ota et al. (2000) reported the association of Armillaria root rot with hard wood species at Kerita and

Jimma. In a recent study, symptoms of Armillaria root rot were also found in plantations in and around Wondo Genet, Munesa Shashemene, Belete/Jimma, Bedele and Aman/Mizan (Gezahgne et al., 2003a). The typical symptoms of Armillaria root rot (white mycelial fan) was found in association with *Pinus patula* at Wondo Genet, Belete, Bedele and Jimma, on *Acacia abysinica* trees, at Wondo Genet and Bedele on stumps of *Juniperus excelsa*, at Wondo Genet on *Cordia alliodora* and *Cedrela odorata* trees in research plots at Aman (Mengistu, 1992; Dagne, 1998; Gezahgne et al., 2003a; 2004).

It is possible to suggest that at least two *Armillaria* species, *A. mellea* and *A. fuscipes* are involved in causing Armillaria root rot. *A. fuscipes* not only affects *P. patula* but also *Cordia alliodora* and *Cedrela odorata* trees. It was also found that this fungus is associated with the two native trees of Ethiopia namely *Acacia abyssinica* and *Juniperus excelsa*. Most plantations in Ethiopia consisted exotic species planted on recently cleared sites where the stumps of native trees serve as source of inoculum to infect newly planted tree species (Gezahgne et al., 2004).

## Stem canker

Pink disease was reported from *Eucalyptus camaldulensis* planted in Pawe, Benshangul Gumuz, northwestern Ethiopia (Gezahgne et al., 2003b). The disease is characterized by branch dieback, stem canker, production of epicormic shoots, and production of pink mycelial growth at the area of infection and in several cases death of trees. The disease is caused by a fungus known as *Erythricium salmonicolor* (Syn *Corticium salmonicolor*) which belongs to the Corticiaceae (Basdiomycotina: Aphyllophorales). Similar disease symptoms were also observed on branches of *Podocarpus falcatus* at Wondo Genet and on *Acacia* species in the Rift Valley (Alemu Gezahegne, pers. observation).

A serious stem canker disease caused by *Conithyrium zuluense* was reported from several localities (areas between Woliso and Jimma, and Wolkite and Sodo) where *Eucalyptus camaldulensis* is growing (Gezahgne et al., 2003a; Alemu et al., 2005). It was estimated that symptoms of coniothyrium stem canker was found on about 50% of *E. camaldulensis* trees growing in these localities. Tests showed that it is pathogenic, hence, *E. camaldulensis*, the widely planted tree species in Ethiopia, appears to be highly susceptible to coniothyrium stem canker. The disease causes stunted growth and reduction of timber quality and strength (Alemu et al., 2005).

The other commonly found stem canker attacking *Eucalyptus* species is botryosphaeria stem canker (Gezahgne et al., 2003a; 2004). It was recorded on *E. globulus, E. saligna, E. grandis* and *E. citrodora* planted at Munessa

Shashemene, Wondo Genet and Menagesha. The fungi involved in causing stem canker on *Eucalyptus* species in Ethiopia was identified as *Botryosphaeria parva* (Alemu et al., 2004). The disease was commonly found on both coppice stems and first generation stands irrespective of the age of the stand. Botryosphaeria stem canker was found to cause the most severe damage on *E. citrodora* trees at Wondo Genet and Belete/Jimma. Botryosphaeria dieback and canker are known to be more pronounced when plants are under stress conditions from drought, frost, water logging and damage from other biotic and abiotic stresses (Wene and Schoeneweiss, 1980; Pusey, 1989; Old et al., 1990). In Ethiopia, these plantations are commonly developed on marginal land where trees are exposed to several growth limiting factors that favour development of botyosphaeria dieback and canker (Alemu et al. 2004).

Four other *Botryosphaeria* species were reported to be found on seeds of *Podocarpus falcatus* and *Prunus africana* (Abdella, 2004; Abdella et al., 2004a). Of these, three are new records. The identity of the two is not yet known. The one recorded from seeds of podocarpus was *Botryosphaeria parva*, while the species from seeds of *Prunus* was reported to be new and described as *Diplodia rosulata* (Abdella et al., 2004a). The damage they inflict to the seeds and seedlings is not yet known. In addition to these, an unidentified species of *Botryosphaeria* was found on cones of *Pinus patula* (Gezahgne et al., 2003a). The ability of this fungus to infect *P. patula* trees have been confirmed in greenhouse and found to be pathogenic (Alemu, 2004).

*Diplodia pinea* (syn = *Spharopsis sapinea*), morpho-type A was the other fungal pathogen found associated with cones of *Pinus patula* (Gezahgne et al., 2003a; Alemu, 2004). Stresses from environmental conditions as well as mechanical damage predispose trees to disease caused by *D. pinea*. The fungus exists in pine cones and stems as endophytes, i.e. it lives with the plant without showing disease symptom until the trees are stressed. The occurrence of *D. pinea* in *P. patula* plantations of Ethiopia has significant implication on the management, utilization and future development of the tree species as the fungus can easily be introduced with seeds. Due attention should also be given not to introduce morpho type C, which is more aggressive than morpho type A.

## Seed-borne fungi

Seed borne fungi pose diverse problems on tree seeds. These include reduction of seed storage life span, rotting of seeds, reduction in seed vigour, reduction in germination, and cause damping off in nurseries (Abdella, 2004). Infected seeds can serve as a medium of transport to pathogens over long distances. According to Abdela (2004), over 250 fungi belonging to Ascomycota, Basidiomycota, and Zygomycota were found associated with seeds of two indigenous tree species, *Podocarpus falcatus* and *Prunus Africana*. The genera including

*Phomopsis/Diaporthe, Phoma, Pestalopsis, Fusarium, Alternaria, Botryosphaeria, Cytospora, Cladosporium, Ulocladium, Nectria, Vericilium* and *Penicilium* represented Ascomycota. The genera representing Basiomycotina included *Peniophora, Polyporus, and Stereum* and Mucor was the only genus representing Zygomycotina (Abdella, 2004). The interaction of these fungi with seeds was categorized into five different types including 1) pathogenic to seeds but with no clear symptom on emerging seedlings, 2) pathogenic to emerging seedlings (germlings) 3) pathogenic to both seeds and seedlings 4) harmless association and, 5) fungi that increased seed germination without causing disease (Abdella et al., 2004b). These categories are in agreement with the categories of Southerland (1995). Some of the seed-borne pathogens such as *Cerospora* sp., *Phoma, Guignardia* sp., *Ulocladium botry* and *U. chartarum* reduced germination of podocarpus seeds. *U. chartarum* for example, caused 50% reduction in seed germination (Abdella, 2004). *Pestalotiopsis* species caused severe damage to roots of the emerging seedlings. *Fusarium oxysporum* and *Polyporus* species caused severe damage in both seeds and seedlings (Abdella, 2004).

## Cytospora canker

Two new *Cytospora* species were reported to be found in association with twigs of *Eucalyptus saligna* (Gezahgne et al., 2003a). These were identified as *Cytpspora abyssinica* and *Cytpspora nitschkii* (Gerard et al., 2005). The importance of these species in causing stem canker and twig dieback in Ethiopia needs further investigation.

## Shoot dieback

Little information is available on the association of shoot dieback disease with indigenous tree species in Ethiopia. One of the recent disease report associated with indigenous trees is that of Abraham (2006), who reported the occurrence of shoot dieback on *Podocarpus* in Menagesha and Munissa Shashemene forests. Based on morphological studies, it was reported that *Alternaria* spp., *Phoma* spp., *Pestaliopsis* sp. and *Fusarium* sp. were commonly found to be associated with shoot dieback symptom. However, further studies are needed to determine which of these species are involved in the development of shoot dieback.

## Insect pests recorded on some forest trees

Research on forest entomology is also at its infant stage. Other than pests recorded on some tree species the information on damage caused by insect pests on trees and tree products is very limited. Insects pose severe damage on tree seeds, seedlings in nurseries, standing trees and tree products. The commonly observed insects include termites, bark beetles, boring insects, chewing insects, defoliating insects, sucking insects and gall makers (Tables 2).

Table 2. Insect pests recorded on tree species in different parts of Ethiopia (Tibebu, 2002).

| Scientific name | Common name | Host tree species | Sites affected |
|---|---|---|---|
| *Macrocerotermes* spp. | Termites | Most tree species in natural and plantation forests | western, southern and eastern parts of Ethiopia |
| *Microterms* spp. | | | |
| *Ancistroterms* sp. | | | |
| *Odontoterms* sp. | | | |
| *Cinara Cupressivora* | Cypress aphid | *Cupressus lusitanica* | Shashemene, Menagesha Suba, Ardayta, Agarfa, Addis Ababa and many other cypress growing areas |
| *Ctenarytaina eucalypti* | Blue gum psyllid | *Eucalyptus globulus* | In most Eucalyptus growing areas |
| *Pineus boerneri* | Pine wooly aphid | *Pinus* spp. | Shashemene Forest Industry Enterprise pine plantations |
| Different spp. | Wood borers and Bark beetles | Different natural and plantation trees | Menagesha Suba, Shashemene and natural and plantation forests in western and southern parts |
| Different spp. | Defoliators | Different natural and plantation trees | Menagesha Suba, Shashemene and natural and plantation forests in western and southern parts |
| Different spp. | Gall makers | Different trees in natural and plantation | Menagesha, Suba, Shashemene and natural and plantation forests in western and southern Ethiopia |

Termites are the most destructive insects especially in most of the natural and plantation forests. Sucking insects like Cypress aphids, (*Cinara cupressivora*), pine woolly aphid and blue gum psyllid (*Ctenarytaina eucalypti***)** are also important in plantation forests.

Termites caused over 90% loss of newly transplanted Eucalyptus seedling in Ethiopia (Abdurahman, 1992). It is also an important pest on a number of other exotic and native tree species.

Cowie et al (1989) reported the occurrence of acacia beetle on acacia trees, speckled tiger moth on *Crotolaria* species, pine wooly aphid on *Pinus halepensis* and sesbania beetle on sesbania trees. Hill and Hadera (1965), Hill (1966) and Tsedeke (1988) and Hill (1989) recorded many insect pest species on different forest trees in Ethiopia (Appendices 1 and 2).

Among insect pests attacking Eucalyptus, the Eucalyptus psyllid, also known as blue gum psyllid is the most common in several localities (Demsash, 1991). It attacks young seedlings in nurseries, plantations and young shoots of coppices causing reduction in shoot growth or even dieback of terminal shoots.

## Seed predation

Argaw and Demel (1999) reported that pre-dispersal predation of different tree species in Acacia woodland of the Rift Valley ranged between 3 and 38%. The amount of seeds that failed to germinate due to insect damage ranged from 7-15%. Tibebu (2002) reported insects associated with fruits/ seeds of *Cordia africana* (Table 3). However, the species of most of these insects were not identified.

Table 3. Insects associated with seeds of *Cordia africana* (Tibebu, 2002).

| **Order** | **Family/species** | **Common name** |
|---|---|---|
| Hymenoptera | Brachonidae/ Phanomeris | Small wasps |
| Diptera | Mycetophilidae | Fungus gnat |
| Diptera | *Psilocephala aldrichi* | Stiletto flies |
| Diptera | Drosophilidae | Vinegar or Pomace flies |
| Diptera | Muscidae/Fannia spp. | - |
| Hymenoptera | Eurytomidae/*Eurytoma* spp. | Seed chalcids |
| Hymenoptera | Torymidae/Pseudotorymus | Seed feeders |
| Hymenoptera | Tersilochus spp. or Ichneumonidee | - |
| Micro lepidoptera | Cosomopterigidae | Small moths |

According to the National Tree Seed Project (1999), insects caused 45, 30 and 20% damage on seeds of *Cordia africana* collected from Sekoru, Arjo and Wondo Genet areas, respectively, and the amount of *Acacia albida* seed damage in Awassa area was 60%. Tibebu (2002) studied pre-dispersal insect seed predators on seeds of these two tree species. Seed predation was reported to be 20% on *Cordia africana* seeds collected from Sekoru, and 8-10% on seeds collected from Denbi, Jimma and Arjo. Post-harvest insect damage on seeds of *Acacia albida* collected from Wonji, Koka and Awassa ranged from 20.5-79.7, 4.2-72.7 and 9.7-91.0%, respectively. Hymenopterans (seed chalcids), small wasps (Branconidae), seed beetles (Bruchidae), Microlepidoptera, and flies were the insects reported by Tibebu (2002).

## Leaf defoliators

An unidentified lepidopterous caterpillar was found causing sever leaf feeding damage on *Croton mycrotachus* trees around Shashemene, Arsi-Negelle, and Siraro. Partial defoliation could cause reduced growth and branch dying whereas continuous or frequent feeding lead to death of the plant (Agena, 2006). *Moringa steneopitala*, a native multipurpose tree species grown for its

edible leaves in southern Ethiopia (Jiru, 1995), is attacked by leaf feeders. According to Demuelenaere (2001), larva of the moth *Noorda blitealis* is involved in the defoliation. Nigusu (2005) reported that the larvae prefer to feed in the early morning of the day and in the rest of the day they hide themselves by folding, rolling, webbing the leaves and boring into the stem of the host plant. *Noorda blitealis* larva is reported to be specific to the *Moringa stenopitala* and no other plant was found to host the pest.

## Cypress aphid

Cypress (*Cupressus lusitanica*), the native tree to Central America, is one of the exotic tree species that has been widely used for establishing plantation forests and for hedging in several eastern, central and southern Africa including Ethiopia. The cypress aphid, *Cinara cupressivora*, formerly thought to be *Cinara cupressi*, has become a damaging pest in Africa since its first introduction in Malawi in 1986 (Chilima, 1994; Ciesla, 1991; Murphy et al., 1996). In Ethiopia, it occurred in 2003/2004 together with an unidentified scale insect on cypress planted for hedge in cities and towns, and in plantations (Alemayhu, 2005). The pest affected the aesthetic value of cypress hedges and above all caused death of many trees in several *Cupressus lusitanica* plantations. According to Watson et al. (1999), the pest has a wide host range including *Juniperus procera*, which is native to Ethiopia. However, its association with and effect on Juiper is not yet confirmed.

## Insect pests associated with wood degradation

Unidentified wood boring beetles and termites are among the important wood degrading agents (Table 4). These insects damage trees in the forest, felled logs, stored timber and wood based products in use (Melaku and Addis, 1987).

Table 4. Wood degrading insects recorded in Ethiopia (after Melaku and Addis, 1987).

| Order | Common name | Type of injury/damage |
|---|---|---|
| **Coleoptera** | | |
| Bostrichidae | Powder post beetles | Powder posting |
| Lytcidae | Powder post beetles | Powder posting |
| Platypodidae | Ambrosia beetles | Pinholes |
| Scolytidae | Ambrosia beetles | Pinholes |
| Hymenoptera | | |
| Formicidae | Ants | Honeycombing |
| Xyelidae | Wood wasps | Grub holes |
| **Isoptera** | Termites | Damage live trees, woods and wood products |
| Termoposidae | Damp wood termites | Damage live trees, woods and wood products |
| Rhinotermitidae | Moist wood termites | Damage live trees, woods and wood products |
| Termitidae | Ground dwelling termites | Damage live trees, woods and wood products |
| Kaloterermitidae | Dry wood termites | Woods and wood products |
| Teredinida and Isopoda | Marine borers | Cause decay of woods |

# Pest management measures

Most of the few studies regarding forest protection focused on the identification of pest species, and thus, there is not much information available on the management of pests in general and that of diseases in particular.

# Insect pest management

## Cultural Control

### Cyprus aphid and scale insects

Application of enough amount of water onto the plant, sanitary measures at the time of pruning, and removing infested plant parts and dried branches are recommended measures to reduce the spread of the insects mainly on hedges (Alemayehu, 2005).

### Traditional methods of wood protection

- Species selection: Some species like *Hagenia abyssinica* (Kosso), *Olea welwitschii* (Damot Woira), *Diospyros abyssinica* (Loko), *Mimusops kummel* (Kolati) and *Juniperus procera* (Tid) are known to be termite resistant by the local people. For this reason, these species are selected for

house construction, for furniture and farm tool manufacturing especially in areas where there is termite problem.

- Ground contact prevention: This can be considered as a proper construction method. Wooden pillars are inserted in pre-bored holes and then filled with gravels or stones and firmly tamped down to keep them up in position. After this operation a basement is constructed from stone parallel with the wooden pillars some centimeters high above ground to reduce direct contact with the ground.
- Soil treatment: The common method local people apply on soil to minimize wood damage is to treat the soil with ash and old/used motor oil.

## Chemical control

### Termites

A trial was carried out in Meki and Gimbi to replace the banned Aldrin 40% WP with Marshal to control termites on *Eucalyptus camaldulensis, E. citriodora, E. saligna and Leucaena leucocephala.* The results indicated that the treated seedlings were less attacked by the pest than the untreated plants. At both locations increment of 23-45% in survival was observed on the treated seedlings. From this it was concluded that Aldrin can be substituted by Marshal at the rate of 10-12.5 g /kg soil (Amsalu, 1991).

### Cyprus aphid and scale insects

Six insecticides namely L-cyhalothrin 5% EC, basudin 60% EC, carbaryl 85% WP, chlorphyrifos 48% EC, malathion 50% EC and imidachloroprid 70% WP were evaluated on hedges at 3 locations in Addis Ababa in 2005. It was reported that all of the insecticides gave 100% control of the aphid. However, the scale insect was not controlled by any of the insecticides tested. Among the insecticides malathion provided 26.4%, basudin 17.7% and carbaryl about 14.0% control of the aphid.

### Impregnation of woods and wood products

Modern wood preservation in Ethiopia began in 1961. Since then the cut *Eucalyptus* poles and other tree species are impregnated with different chemicals for the preservation of the wood against termites and other insect pests by different organizations such as the Ethiopian Electric Light and Power Authority (EELPA) and the Ethiopian Telecommunication Authority (ETA).

# Biological control

## Moringa leaf defoliator

Nigusu (2005) indicated that an ant (*Myrmilaria* sp.) is an important predator on the caterpillar of *Noorda blitealis*. Similarly, a praying mantid in the family Hymenopodidae was also found feeding on the caterpillar.

## Cypress aphid

The parasitic wasp, *Pauesia juniperorum* which showed good performance in Kenya, Malawi and other East African countries on the aphid (Chilima, 1995), was introduced into the country and is being reared in the Forestry Research Center, Addis Ababa. Regular scouting and monitoring of the natural enemy is important. The wasp has been introduced, reared and released in Munessa Shashemen forest and its impact in reducing the population build up and damage of the aphids is under investigation.

## Botanical

According to Nigusu (2005), application of 50 $g^{-l}$ and 75 $g^{-l}$ seed extracts of *Melia* was as effective as the chemical insecticide Durshan 48%. The botanical is reported to deter oviposition of aphids without affecting the predator ant.

# Other pests

## Pine woolly aphid, *Pineus boerneri*

Pine woolly aphid was first recorded in Kenya in 1968. It was originated from Australia. The pest was recorded in the Shashemene Forest Industry Enterprise pine plantation. However, its identification needs to be confirmed.

## Pine needle aphid, *Eulacnus rileyi*

Pine needle aphid is an external parasite on needle of pinus species. The preferred host is *Pinus patula*. It was first recorded in Kenya in 1988. The affected needles turn yellow and drop prematurely. On its own, this pest does not cause tree mortality but in combination with pine wooly aphid, it causes loss of growth and sometimes death. The pest is not observed in the country to date but requires due attention as it is known to cause serious damage in the neighboring Kenya.

## *Cinara pinivora*

*Cinara pinivora* is a new pest of pine in Africa. It was first reported in Malawi in 2001, then in Tanzania and Kenya in 2004. It is found in Australia, Argentina Uruguay and Brazil (Blackman and Eastop, 1984). The aphid's dense colonies

are found distributed on all parts of the plant. The damage starts as coloration and premature fall of needles and change of some branches in to a brown colour. This pest is not observed in the country to date.

# Conclusion and recommendations

The significance of forest pest research attracted little attention in the past. The information available on forest diseases from Ethiopia is scanty and often recorded in unpublished reports.

This review tried to put together the available information as much a possible. The experience and knowledge from other parts of the world are also included in order to fill the information gap and to create awareness. The rapidly growing demand for forest products in Ethiopia necessitates the expansion of exotic plantations. The introduction of exotic tree species into Ethiopia commenced a century ago. Up to now not less than 160 exotic trees and shrubs have been introduced into the country. In a situation where exotic plantations substitute the native forests, an outbreak of disease could severely damage plantations.

Diseases have a serious impact on exotic plantations in various parts of Africa. Several of these have been discussed in this review. It must be expected that other diseases that negatively affect exotic plantation forestry could pop up in the future. Thus, every effort must be made to put in place the means to deal with this alarming situation so that the problem is minimized. Adequate information on exotic pests of plantations should be obtained. It is also equally important to understand risks of diseases to various tree species planted in different parts of the country. This knowledge will provide a firm base on which to develop appropriate disease management strategies.

# Gaps and challenges

## Lack of awareness

As it can be seen from the review most research work on tree diseases are very recent. Death of trees and seedlings were commonly attributed to poor species site matching, adverse climatic conditions and poor management or tending practices. The role of biotic factors in causing damage to trees was less recognized and much research has not been conducted.

### Shortage of trained manpower

Shortage of trained work force in the area of tree diseases and insect pests is a major constraint to date and because of this much research work has not been undertaken.

### Inadequate research facility

Lack of specialized laboratory for forest protection research is another major constraint that limits studies on tree diseases. Currently the focus of most plant pathology research work is on food crops.

### Inadequate research coverage

The scope and coverage of research in terms of forest type, agro-ecology and tree species is very much limited. The focus of most studies was on identifying the causative agents and much has not been done on the impacts of diseases and insect pests and their management options.

## Prospects

### Capacity building

Building research capacity, mainly in strengthening research personnel and research facility is very urgent.

### Develop strategy and priority

It is important to create a forum for discussing issues related to forest protection, mainly focusing on tree diseases, insect pests and parasitic plants in order to outline their importance, develop a strategy, set research priority and establish linkage with researchers in the field of plant protection. Most of the available information on tree diseases focused on identification of the organisms involved in causing the diseases, and the disease management aspect is inadequately addressed.

### Strengthen collaboration and linkage

The research capacity on tree disease and insect pests is limited. It is therefore to consider establishing collaboration and linkage with research laborites at different research centers and higher learning institutions within the country as well as abroad.

### Issue of quarantine

The introduction of seeds of trees as well as lumber is increasing which may facilitate the introduction of new diseases and insect pests. Hence, strong enforcement of the quarantine procedure on tree seeds, different forest products as well as wooden packages is important and need to get due attention.

Appendix 1. Insect pests recorded on different forest tree species in Ethiopia (after Hill and Hadera, 1965; Hill, 1966 and Tsedeke 1988).

| Scientific name | Common name | Host tree species |
|---|---|---|
| **Acarina** | | |
| **Tetranychidae** | | |
| *Eutetranychus orientalis* | Orient mite | *Ficus carica* |
| **Orthoptera** | | |
| **Acrididae** | | |
| *Cyrtacanthacris tatarica* | Brown spotted grasshopper | *Acacia abyssinica*<br>*A. cynophilla, A. melanoxylon*<br>*Acacia* spp. |
| **Eumastacidae** | | |
| *Symbelia biplagiata* | Acacia grasshopper | *Acacia* spp. |
| **Pyrgomorphidae** | | |
| *Phymateus pulcherimus* | Bush locust | *Acacia* spp. |
| *Phymateus viridipes* | Bush locust | *Eucalyptus* spp.<br>*Ficus carica, F. dekdekena* |
| **Hemiptera** | | |
| **Tingiddae** | | |
| *Horvathula uniseriata* | - | *Cordia Africana* |
| *Compseuta ornatella* | - | *Podocarpus gracilior/ P. falcatus* |
| **Homoptera** | | |
| **Triozidae** | | |
| *Trioza erytreae* | Citrus psyllid | *F. sycomorus* |
| **Aphididae** | | |
| *Aphis gossypii* | Cotton aphid | *F. sycomorus, F. dekdekena* |
| *Aphis* sp. gossypii group | Aphid | *Jacaranda mimosaefolia* |
| *Hyadaphis corianderi* | Coriande aphid | *Jacaranda mimosaefolia* |
| *Myzus* sp. | Aphid | *Jacaranda mimosaefolia* |
| *Neophyllaphis grobleri* | - | *Podocarpus gracilior* |
| **Margarodidae** | | |
| *Icerya purchasi* | Cottony cushion scale | *A. cynophilla, Acacia* spp., *Albizia ferruginia* |
| **Coccidae** | | |
| *Ceroplastes africanus* | African waxy scale | *Acacia* spp., *Albizia ferruginia* |
| *C. destructor* | Coffee waxy scale | *Ficus benjamina, F. dekdekena* |
| *C. rusci* | Fig wax scale | *Ficus elastica, F. palamata, F. vasta, other Ficus* spp. |
| *Ceroplastes* spp. | Waxy scale | *Croton macrostychus* |
| *Coccus hesperidum* | Soft brown scale | *Ficus carica* |
| *Saissetia coffeae* | Helmet scale | *F. carica, F. dekdekena* |
| *S. oleae* | Olive scale | *Acacia* spp., *Croton macrostychus* |
| *S. somereni* | Someren scale | *Ficus dekdeken* |
| *Saissetia* sp. | Someren scale | *Cordia Africana, Ficus dekdeken* |
| **Diaspididae** | | |
| *Chrysomphalus dictyospermi* | Orange scale | *F. carica* |
| *Lepidosaphes beckiii* | Mussel scale | *F. carica* |

Appendix 1. Contd.

| Scientific name | Common name | Host tree species |
|---|---|---|
| *Spinaspidiotus fissidens* | - | *Carissa achimperi* |
| **Heteroptera** | | |
| **Pentatomida** | | |
| *Cryptacrus comes* form *pinguis* | Loquat bug | *C. macrostycus* |
| **Lepidoptera** | | |
| **Bombycidae** | | |
| *Ocinara ficicola* | Fig moth | *Ficus* spp. |
| **Noctuidae** | | |
| *Ctenoplusia limbirena* | Plusia worm | *F. carica* |
| *Eublema olivacea* | Fig worm | *Ficus* spp. |
| *Heliothis armigera* | Africa bollworm | *F. carica* |
| **Saturiniidae** | | |
| *Holocerina smilax* | - | |
| **Diptera** | | |
| **Tephritidae** | | |
| *Didacus vetebratus* | Melon fly | *C. macrostychus* |
| **Coleoptera** | | |
| **Scarabaeidae** | | |
| *Pachnoda abyssinica* | Yellow rose chafer | *Acacia abyssinica* |
| *P. crassa fairmairei* | Preal millet chafer | *Acacia* spp. |
| *P. massajae* | Yellow headed chfer | *Acacia* spp. |
| *P. interrupta* | Sorghum chafer | *Acacia* spp. |
| *P. peregrina* | Mango chafer | *Acacia* spp. |
| *P. sobrina* | Citrus chafer | *Acacia* spp. |
| **Buprestidae** | | |
| *Chrysobothris dorsata* | Chat borer | *F. carica* |
| **Bostrychidae** | | |
| *Abate inistincta*. | Black borer | *Acacia* spp. |
| *Abate monachus*. | Black borer | *Acacia* spp. |
| *Abate* terebrans | Black borer | *Acacia* spp. |
| **Nitidulidae** | | |
| *Cantharoonemis felderi* | Eucalyptus beetle | *Eucalyptus* spp., *F. dekdekena* |
| **Lagridae** | | |
| *Lagria villosa* | Metalic leaf beetle | *F. carica* |
| **Melcidae** | | |
| *Mylabris designata.* | Pollen beetle | *Acacia* spp. |
| *Mylabris flavoguttata* | Pollen beetle | *Acacia* spp. |
| **Cerambycidae** | | |
| *Phrynotopsis variegata* | Fig borer | *F. carica* |
| **Chrysomelidae** | | |
| *Hyperacantha inaequalis* | Cucubmber beetle | *F. carica* |
| *Megalognatha aenea* | Acacia beetle | *Acacia* spp. |
| **Coccinellidae** | | |
| *Rodolia* spp. | - | *Acacia* sp. |

Appendix 1. Contd.

| Scientific name | Common name | Host tree species |
|---|---|---|
| **Curculionidae** | | |
| *Amblyrhinus brunneus* | Almond weevil | *Acacia* spp. |
| **Isopteran** | | |
| **Termitidae** | | |
| *Odontotermes anceps* | Termite | *Cordial africana, Eucalyptus globulus* |
| **Kalotermitidae** | | |
| *Epicalotermes aethiopicus* | | *Acacia* spp. |
| **Rhinotermitidae** | | |
| *Reticulitermes aethiopicus* | | *Acacia* spp. |
| **Hemiptera** | | |
| **Cicadidae** | | |
| *Ioba veligera* | Cicada | *Acacia* spp. |

App. 2: Some insect pests recorded on different tree seedlings and saplings in Ethiopia.

| Scientific name | Common name | Host tree | Ref. |
|---|---|---|---|
| **Orthoptera** | | | |
| **Gryllidae** | | | |
| *Acheta* spp. | Field crickets | seedlings, saplings | 54 |
| *Brachytrupes membranaceus* | Tobacco cricket | seedlings, saplings | 54 |
| **Gryllotalpidae** | | | |
| *Gryllotalpa africana* | African mole cricket | seedlings, saplings | 54 |
| **Tettigoniidae** | | | |
| *Eugasteroides loricatus* | Spiny bush-cricket | seedlings, saplings | 54 |
| **Acrididae** | | | |
| *Anacridium* spp. | Tree locusts | seedlings, saplings, *Acacia* spp. | 53, 54 |
| *Catantops* sp. | Tree grasshopper | seedlings, saplings, Eucalyptus | 54 |
| **Isoptera** | | | |
| **Termitidae** | | | |
| *Macrotermes* sp. | Termites | seedlings, saplings, Eucalyptus | 54 |
| **Macrotermtidae** | | | |
| *Odontotermes* spp. | termites | Eucalyptus | 54 |
| **Hemiptera** | | | |
| **Cicadilidae** | | | |
| *Ioba veligera* | Cicada | Acacia | 54 |
| **Coreidae** | | | |
| *Leptoglossus australis* | Leaf-footed plant bug | Eucalyptus | 54 |
| **Psylildae** | | | |
| *Ctenarytaina eucalypti* | Eucalyptus psyllid | Eucalyptus | 54 |
| **Heteroptera** | | | |
| **Miridae** | | | |

Appendix 2: Contd.

| Scientific name | Common name | Host tree | Ref. |
|---|---|---|---|
| *Helopeltis bergrothi* | Mosquito bug | Eucalyptus | |
| **Pentatomidae** | | | |
| *Agonoscelis* spp. | Stink bug | Eucalyptus | 54 |
| **Homoptera** | | | |
| **Aphididae** | | | |
| *Myzus* spp. | aphids | seedlings, saplings | 54 |
| **Margarodidae** | | | |
| *Icerya purchasi* | Cottony cushion scale | seedlings, saplings, Acacia, Eucalyptus | 53, 54 |
| **Pseudococcidae** | | | |
| *Planococcus* spp | Mealybug | Acacia | 54 |
| **Coccidae** | | | |
| *Ceroplastes* spp. | Waxy scales | Acacia | 54 |
| **Diaspidae** | | | |
| *Aspidoproctus* spp. | Armoured scale | Acacia | 54 |
| *Hemiberlesia rapax* | Green scale | Eucalyptus | 54 |
| *Hemiberlesia* spp. | Pine armoured scale | Acacia | 54 |
| **Coleopteran** | | | |
| **Buperstidae** | | | |
| *Agrilus* spp. | Red-necked cane borer | Acacia, Eucalyptus | 54 |
| **Bostrichidae** | | | |
| *Apate* spp. | Black borer | Acacia, Eucalyptus, | 54 |
| *Xyloperthodes* spp. | - | Acacia | 54 |
| **Cerambycidae** | | | |
| *Acanthophorus confinis* | Giant longhorn | Eucalyptus | 54 |
| *Paranaleptes trifasciata* | Longhorn beetle | Acacia, Eucalyptus | |
| **Scarabaeidae** | | | |
| *Schizonycha* spp. | White grubs | seedlings, saplings, Acacia, Eucalyptus | 54 |
| **Curculionidae** | | | |
| *Nematocerus* spp. | Shiny cereal weevils | Acacia, Eucalyptus | 54 |
| Tenebrionidae | | | |
| *Gonocephalum* spp. | Darkling beetles | seedlings, saplings, Acacia | 54 |
| **Chrysomelidae** | | | |
| *Megalognatha* spp. | Leaf beetle | Acacia | 54 |
| **Buprestidae** | | | |
| *Chrysobothris* spp. | Chat borer | Acacia | 54 |
| **Lyctidae** | | | |
| *Lyctus brunneus* | - | Eucalyptus | 54 |
| **Lepidoptera** | | | |
| **Geometridae** | | | |
| *Ascotis selenaria* | Giant looper | Eucalyptus | 54 |
| **Lasiocampidae** | Lappet moths | Acacia | 54 |
| *Gonometa* spp. | | | |
| *Taragama* spp. | - | Acacia | 54 |

Appendix 2: Contd.

| Scientific name | Common name | Host tree | Ref. |
|---|---|---|---|
| **Lymantidae** | | | |
| *Euproctis* spp. | Tussock moths | Acacia, Eucalyptus | 54 |
| **Noctuidae** | | | |
| *Agrotis* spp. | cutworms | seedlings, saplings, Eucalyptus | 54 |
| *Sphingomorpha chlorea* | - | Acacia | 54 |
| *Oxygia* spp. | Tussock moths | Acacia, Eucalyptus | 54 |
| **Pieridae** | | | |
| *Catopsila* spp. | Migrant butterflies | Acacia | 54 |
| **Psychidae** | | | |
| *Clania cervinia* | Bagworm | Acacia | 54 |
| **Saturniidae** | | | |
| *Lobobunea tyrrhea* | Emperor moth | Acacia | 54 |
| *Nudaurelia wahlbergi* | - | Acacia | 54 |
| **Formicidae** | | | |
| *Dorylus* spp. | Gojam red ant | seedlings, saplings | 54 |

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# Review of Research on Migratory Insect and Vertebrate Pests in Ethiopia

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## Introduction

Migratory insect pests attacking crops in Ethiopia include the Desert Locust and the African armyworm (*Spodoptera exempta*), while vertebrate pests include birds and rodents.

The Desert Locust, *Schistocerca gregaria* (Forskal) is the most destructive sporadic pest in Ethiopia. It is capable of causing considerable damage to agricultural crops and wild vegetation in the country. However, there is very little information regarding the magnitude of damage to crops and yield losses caused by the pest in the country. The figure frequently quoted is that caused in 1957, which was estimated at 167,000 tons of grain (Meizingen, 1993). It was a conservative estimate considering the areas infested and the feeding habits of the pest. There are vast areas within Ethiopia that are suitable for the Desert Locust breeding and population development. The country can also be invaded by swarms coming from neighbouring countries (Awetahegn, 1995). There had been a number of Desert Locust upsurges/plagues in the country during the last four decades. In the years 1967- 69, 1977-1979, 1986-89, and 1993 serious upsurges which caused widespread damage were recorded. During 1993 upsurge, over 80,000 ha were treated using 44,891 liters and 26,956 kg of various insecticides (Aynekulu, 1995). In 2005, a small scale infestation of about 30 hectares was controlled in Tigray Region. The swarm was originated from a neighbouring country (DLCO-EA, 2005).

The African armyworm, *Spodoptera exempta* (walk.) is a serious sporadic pest of cereal crops such as maize, sorghum, rice, millet, wheat, teff and rangeland grasses. During heavy outbreak years nymphal densities of over 1,000 per square meter were recorded (DLCO-EA, 1992). The nymphs are observed to be voracious feeders and this clearly indicates the extent of loss that could be resulted from pest densities of such magnitude. Infested areas vary from year to

year. According to Kassahun (2005), the areas that were infested by armyworms during the years 1986, 1994, 1996, 1997, 1999 and 2004 were 92,396, 366,414, 246,186, 78, 437, 92,449 and 11,160 hectares, respectively.

Bird damage to crops occurs throughout the country with the magnitude varying from one geographical location to the other, the type of bird pests involved and crops attacked. The principal bird pest problem in the country is the Red–billed quelea on sorghum grown in lowland areas. Among the migratory pests, the quelea bird has become more regular in recent years compared to the Desert Locust and African Armyworm. Although quelea is the major bird pest in the country, a number of other bird species are also recorded on various crops. Quantitative damage assessment in the Awash River Basin indicated that the average annual loss without control on sorghum crop alone ranges from 27,000-40,000 metric tones or 51% of the expected yield. Owing to this huge amount of loss, aerial spraying of quelea with an avicide was initiated in 1978. Since then, not less than 10 million birds were annually killed and some degree of control was achieved as a result (Gizachew, 2005). Research on bird pest problem was initiated in 1975 when a national bird control project was initiated through FAO/UNDP assistance to the then Ministry of Agriculture (now MoARD). The project focused on quelea biology, ecology, distribution and movement patterns. Quelea incidence in crop growing areas was determined and yield loss to sorghum in the Awash River Basin was quantified. Field and laboratory trials were conducted on some candidate avicides and repellents in a quest for alternative bird control products in terms of efficiency, economics and environmental safety. The project was terminated in 1981 and the Ministry of Agriculture took over the bird control programme. Since then no bird pest research was conducted in any one of the research institutions in the country (Gizachew, 2005).

Rodents have been a problem in Ethiopian agriculture for a long time. Although no detailed loss assessment studies have been conducted, reports from the Ministry of Agriculture field staff indicate that rats destroy and consume up to 15-20% of grain yield. It was estimated that a farmer loses every year an average of 20 birr per rat in store and 5-10 birr per rat in the field. Periodic population explosion is usually associated with severe damage. Settlement sites are becoming one of the rodent outbreak areas. In these areas, in addition to pre - and post-harvest losses, forestation sites, seedling nurseries, and livestocks were threatened (Merid, 1988). Zinc phosphide has been the most frequently used rodenticide for the control of rodent outbreaks, because of its overnight killing effect. However, zinc phosphide is known to cause bait shyness in rodents ingesting sublethal doses and leads to limited control success. Besides, it is broadly toxic, so that the risk to non-target animals is high. At present,

anticoagulants are becoming more popular for the control of rodents than acute toxicants because of their efficacy and safety (Merid, 1988).

Currently, chemical control is the most commonly used method for the control of migrant pests and rodents in the country. However, this method has a potential threat to human health and the environment. Some of the limitations of chemical control include environmental pollution, bioconcentration in the food chain, destruction of natural enemies and beneficial insects (e.g. bees), health hazard to workers and non-target organisms (USAID, 1991). Therefore, there is an urgent need for the development of effective and environmentally friendly alternatives to chemical control. The following review covers highlights of research activities conducted on the Desert Locust, African armyworm, Quelea birds and rodent pests from 1985-2006 in this country.

# Research findings

## Locusts

### Species recorded

The major locust species recorded in the country are the Desert Locust (*Schistocerca gregaria* (Forskal), the Migratory Locust (*Locusta migratoria migratorioides* (Reiche and Fairmaire), Tree Locust (*Anacridium melanorhodon* (Walker), and *Anacridium wernerellum* (Karny) (Abdurahman, 1995).

### Basic studies

The status and distribution of recession populations of the Desert Locust were extracted from historical data for the following periods: 1963-1967, 1970-1984 and 1989-1999. From 1963-1967 periods, all the years were recession periods. For the 1970-1986, the years 1970, 1971, 1975, 1980 and 1984 were the recession years. For the periods 1989-1999, the recession years were 1990, 1991, 1992, 1994 and 1999. The other years were marked by upsurges, outbreaks and decline (Manyazewal, 2001).

The source of data for this review is mainly the DLCO-EA archives, except for the 1960s recession periods for which data was obtained from the Natural Resources Institute (NRI) of the United Kingdom. These data were entered into a computer program known as Reconnaissance and Management System of the Environment of *Schistocerca* (RAMSES). The version of RAMSES used in the study is known as Ethiopian Locust Management Analysis Tool (ETLMAT) (Manyazewal, 2001). Situation maps for the Desert Locust and rainfall were produced using inquiry reports. The locust situation maps were used to analyze

the distribution of the Desert Locust and other locust species. A total of 1980 situation maps were produced, which include maps on the Desert Locust and rainfall observation, separate or both in one map. Out of these maps, 1963, 1967, 1970 and 1986 were selected for detailed analysis (Manyazewal, 2001).

The results of the study indicate that plagues originate mainly from the surrounding countries, whereas upsurges and outbreaks of the Desert Locust populations can originate within the country as well as from the neighbouring countries. The study showed that in order to manage the Desert Locust plague, upsurges and outbreaks effectively it is necessary to monitor the Desert Locust situation in the country as well as in the neighbouring countries (Manyazewal, 2001).

# Control measures

## Developing new bio-control agents

Fungal pathogen surveys were conducted in Tigrai and Amhara Regional States in 1997/98 to identify bio-control agents that could be used for the control of locusts and grasshoppers. Ten fungal isolates were collected in the areas surveyed. Out of these, eight were bioassayed on fifth instars of *Schistocerca gregaria*. ICIPE 30 (*Metarhizium anisopliae)* was included in the study for comparison. The fungal isolates were applied at the rate of 2 µl of 5 x $10^7$ conidia / ml. The control insects were treated with 2 µl of oil (Seneshaw *et al.*, 2003). Insect mortality was recorded daily for 21 days beginning from the second day after the treatment. The two most virulent isolates were further bio-assayed in comparison with ICIPE 30. The results of the bioassay showed that isolate FF was more virulent than ICIPE 30 (Table 1). Depending on the preliminary bioassay, the isolates were categorized as low (CC and DD), intermediate (GG, AK, HH and AA) and highly virulent (FF). The isolates FF, ICIPE 30 and EE caused 90-100% mortality in 11 days after inoculation (Seneshaw et al., 2003).

Extensive surveys were also conducted by the Desert Locust Control Organization for eastern Africa (DLCO–EA) in locust habitats in different parts of the country to identify fungal pathogens that could be used for the control of the Desert Locusts and grasshoppers. Over 107 isolates were collected in the areas surveyed. Some of the isolates were bio-assayed against the Desert Locust and the Migratory Locust and they performed as good as the commercially available product, Green Muscle® (*Metarhizium anisopliae var. acridum*, IMI 330189). The isolates tested belong to the genera *Beauveria and Metarhizium* (DLCO–EA, 2004). Significant differences were observed between the isolates and the control. The average number of days to 50% mortality was 8.5 and 8.3 days for the Desert Locust and the Migratory Locust,

respectively. The average number of days to 50% mortality for IMI330189, the standard, was 9 days (DLCO–EA, 2004). The average number of days to 50% mortality was higher for *S. gregaria* than that of *Locusta migratoria*.

Table 1. Mean percentage mortality on day 11 of fifth instar *S. gregaria* inoculated with various fungal isolates at dose of 5 x $10^7$ Conidia/ml in peanut oil (Seneshaw et al., 2003).

| Fungal isolates | Mortality (%)* (corrected) | Median lethal time (± SD) |
|---|---|---|
| *Beauveria bassiana FF* | 100[a] | 6 .71 ± 2.32 |
| *Metarhizium anisopliae (ICIPE 30)* | 90 (89.5)[ab] | 6.67 ± 3.44 |
| *M. anisopliae EE* | 90 (88.5)[ab] | 8.00 ±2.37 |
| *B. bassiana GG* | 85 (83.3)[bc] | 8.60 ± 3.46 |
| *B. bassiana AK* | 80 (76.5)[bc] | 8.00 ±4.04 |
| *B. bassiana HH* | 75 (72.2)[bc] | 8.40 ±3.04 |
| *Paeciliomyces sp. AA* | 60 (55.6)[d] | 9.00 ±6.36 |
| *B. bassiana CC* | 40 (33.3)[e] | 13.5 ± 4.77 |
| *B. bassiana DD* | 38 (31.4)[e] | 11.6 ±4.58 |

* = corrected mortality

Values followed by the same letter(s) within a column are not significantly different from each other at P= 0.001 level of probability (Duncan's Multiple Range Test).

Further tests conducted on *Metarhizium* isolates, namely DLCO26 and DLCO28, and IMI330189 showed the relative number of days to 50% mortality for *Schistocerca gregaria* to be 10, 9 and 11, and for *Locusta migratoria* 8, 7 and 9, respectively (DLCO-EA, 2004). Symmetrical virulence was also observed between *Locusta* and *Schistocerca* in DLCO26 and DLCO28 and IMI330189. Across the tests, *Locusta was* observed to be more susceptible to the isolates evaluated than *Schistocerca* gregaria (DLCO-EA, 2004).

## Field evaluation of the efficacy of Green Muscle® (*Metarhizium anisopliae var. acridum)* against the Desert Locust and grasshoppers

Green Muscle® is a bio-pesticide that is currently available on the market for the control of locusts and grasshoppers. It is produced and marketed by Biological Control Product (BCP) Company of South Africa. It is registered for locust control purposes in the Sudan and in some countries in West Africa. It is also included in the FAO's Desert Locust Pesticide Referee Group list of recommended products for the control of locusts and grasshoppers in environmentally sensitive areas (BCP, 2002). The efficacy of Green Muscle® against mixed populations of grasshoppers was evaluated under field conditions in central and eastern Ethiopia (Emiru, 2004, DLCO-EA, 2006a), respectively. The field evaluation in central Ethiopia was conducted in the Amhara Regional

State at two sites, namely Rasa (095433N/400337E), 255 km northeast of Addis Ababa and in Shoa Robit (100054N/395337E), 225 km northeast of Addis Ababa during the 2003 main rainy season (Emiru, 2004). The plot size was 600 $m^2$ and with a spacing of 50 m between treatments. The experimental design was a randomized complete block with three replications. The treatments tested were Green Muscle® conidia, an oil miscible flowable concentrate (OF formulation) and fenitrothion 95% ULV, which is a standard product currently used for the control of locusts and grasshoppers in the country, and an untreated check. Green Muscle® was applied at the rate of 2.5 l/ha and fenitrothion 95% ULV at recommended rate (500 gm a.i /ha). Battery operated ULVA+ sprayer was used for the application of the treatments.

Mortality was assessed daily throughout the post treatment periods starting from the second day after applications. Live grasshoppers were also collected from the field and placed in cages for natural mortality assessment. The effects of the treatments on non–target organisms were also studied by collecting dead or moribund non-target organisms.

The results of the first field trial showed a cumulative percentage mortality of grasshoppers treated with fungus to be between 0-19.78%, 0-11.77% for the untreated control, and 33.33-89.19% for insecticide treated grasshoppers. The results of the second trial showed that the percentage mortality of fungus treated insects (pooled data) vary from 10% at day 15 and 16-72% at 4 days after treatment (dat). The mortality in the control plots varied from 0 at day 15 and 17-48% at 2 dat. Mortality in the insecticide treated plots was as high as 92% during the first four days after application (Emiru, 2004).

The efficacy of Green Muscle® against the Desert Locust hoppers was also evaluated in eastern Ethiopia during the rainy season, 2006 (DLCO–EA, 2006a). The experimental design was a completely randomized block with three replications. The plot size was 4m x 5m (20 $m^2$ ) with each plot enclosed by a plastic fence (Boomas) one-meter high and the top covered by a fabric similar to that used to make mosquito net to prevent locusts moving out of the plots and prevent birds from picking locusts. The treatments tested were Green Muscle®, fenitrothion 96% ULV as reference product and an untreated control. Green Muscle® was applied at the rate of 2 lt/ha and fenitrothion 96% ULV at 0.520 lt/ha. ULVA + spinning disc sprayer was used for the application of the treatments.

Just before treatment, 425 third to fourth instars of the Desert Locust hoppers (reared in the Desert Locust Control Organization for Eastern Africa (DLCO-EA) field station in Dire Dawa) were released in each plot. Immediately after treatment, samples of 25 locust hoppers were collected from each plot and kept

separately under shade in aluminum cages of 25 x 25 x 30 cm. The cages were cleaned daily and the locusts were fed with untreated grass. Dead locusts were also collected daily and incubated for 24 hours in petri dishes with a moist filter paper to check for mycosis. Assessment of mortality in the field was carried out at three days interval for 21 days by counting dead and live hoppers. Dead hoppers in *Metarhizium* treated plots and control were incubated in moist chamber to establish the differential cause of mortality. Dead non-target organisms were also collected to find out the environmental impact of *Metarhizium*. The data collected both in the field and in the cages were transformed into square root and analyzed by SAS statistical program.

The results of the field trials are shown in Tables 2. Although during these periods the reduction in plots treated with Green Muscle were slightly higher than the untreated plots, it is unlikely that *Metarhizium* could act as fast. However, this reduction could be due to the natural mortality factors and to escaping. The population counts after day 3 in the untreated plots remained almost constant over the whole observation period, while the counts in the plots treated with Green Muscle declined with time and differed significantly from the control plots. In the cage trial, the highest mortality occurred on day 9 and 100% was recorded by day 14, while during this period only 13.3% mortality was recorded in control cages (DLCO – EA, 2006a).

Table 2. Mean number of live hoppers in treated and untreated boomas population in the field in Dire Dawa (DLCO – EA, 2006a).

| **Days** | **Hopper count** | | |
|---|---|---|---|
| | **Green Muscle** | **Fenitrothion** | **Control** |
| 0 | 400 | 139.3 | 400 |
| 3 | 255 | 0 | 322.7 |
| 6 | 241.7 | 0 | 302 |
| 9 | 211.3 | 0 | 301 |
| 12 | 168.7 | 0 | 301 |
| 15 | 145.3 | 0 | 301 |
| 18 | 103.7 | 0 | 298.3 |
| 21 | 63.7 | 0 | 294.7 |

## Evaluation of different insecticides against the Desert Locust in the laboratory

Organophosphates (OPs), carbamates, pyrethroids, combinations of OPs and pyrethroids, and a phenyl pyrazole insecticides were evaluated against the Desert Locust adults and hoppers in the laboratory. Fenitrothion (12.0 µg/g), chlorpyrifos (7.0 µg/g), Polytrin-C (2.5 µg/g). deltanet (4.0 µg/g), and Fipronil (0.025µg/g) provided 100% mortality when applied topically. The persistence of the pesticides in treated wheat seedlings were 24 and 15 days for Fipronil and Polytrin-C, respectively, 10 days each for Fenitrothion and Hexaflumuron, 5 days each for Deltanet and Chlorpyrifos – methyl (Muinamia, 1995).

## Evaluation of Carbosulfan on non - target species

Carbosulfan (Marshal) 200 ULV was evaluated in the field and cage on arthropod complex in the Desert Locust habitat in eastern Ethiopia during the 1994 dry season. Grasshoppers and planthoppers (Cercopids) were the most dominant arthropods in the study site (Muinamia *et al.*, 1994).

**Field trial:** The field trials were conducted at Hurso, 20 km west of Dire Dawa and Ganda Tesfa, an irrigated area to the West of Dire Dawa. The treatments tested were carbosulfan 200 ULV at the rate of 125 g/ha, and standard insecticides, namely fenitrothion (Sumithion) 96% Tech. and chlorpyrifos (Dursban) 450 ULV at 500 g/ha and 225 g/ha, respectively. The plot size was 30 m x 175 m and the insecticides were applied with hand-held micro ULVA sprayer. Sticky traps were spread out randomly immediately before treatment and collected after 24 hours. The insects and other arthropods caught on the sticky traps were carefully removed from the disc and transferred to containers with preservation media for laboratory identification.

**Cage trial**: Cylindrical cages, 20 cm in diameter and 60 cm high were placed in the field at distances sufficient to avoid drifts between treatments or replicates. Several grasshopper species caught in the sweepnet were introduced into the cages, sprayed with any of the three insecticides at the pre-determined rates and mortality was assessed. Fresh grasshoppers were again introduced into the treated cages 24 and 72 hours after treatment and mortality was observed for persistence on sprayed substrate. Carbosulfan 200 ULV did not show any serious effect on non-target species compared to the standard insecticides. No undesirable effects were observed on the vertebrates in the habitat. However, the study showed that carbosulfan should not be sprayed when the crops/plants are in bloom stage as a wide variety of pollinators were attracted to some of the trees in bloom stage (Muinamia et al., 1994).

## Environmental impacts of insecticides used against the Desert Locust

The effects of insecticides used for the Desert Locust control on non-target insects and other arthropods were studied in the locust habitats in eastern Ethiopia. The field trial was conducted near Hurso, 25 km west of Dire Dawa. The insecticides tested were fipronil 12.5 ULV, a phenyl pyrazol insecticide at two levels, 10 and 15 g a.i./ha and fenitrothion 96% Technical. The plot size was 30 m x 175 m and the treatments were replicated two times. Pre-treatment samples were taken using sticky traps to determine the density and diversity of the arthropod fauna. The insecticides were applied by hand-held micro ULVA sprayer. The results of the field trial are shown in Tables 3 and 4.

Table 3. Post spray assessment of grasshopper population at Hurso experimental site (Tessema and Muinamia, 2001).

| Treatment | Time after treat. (hrs) | Flush counts (Alive) | | 100 $m^2$ (dead) |
|---|---|---|---|---|
| | | Number flushed* | Calculated density/ha | |
| Fipronil 10g/ha | 48 | 9 | 225 | 5 |
| Fipronil 15g/ha | 48 | 3 | 75 | 4.3 |
| Fenitrothion 500g/ha | 48 | 18 | 438 | 1.4* |
| Untreated check | 48 | 43 | 1075 | 0 |

* Average of 2 reps, HAT = hours after treatment

Table 4. Post spray recovery of non-target arthropods in the Desert Locust Habitat (Tessema and Muinamia, 2001).

| Treatments | Live arthropod counts after different periods | | | | |
|---|---|---|---|---|---|
| | 24 hrs | 48 hrs | 72 hrs | 5 days | 10 days |
| Fipronil 10 g/ha | 100 | 95 | - | 59.5 | 134 |
| Fipronil 15 g/ha | - | 60.5 | 100.5 | 127 | 151 |
| Fenitrothion | - | - | - | - | - |
| Untreated check | 128 | 311 | - | 323 | 419 |

* Mainly leaf hoppers, grasshoppers and Dipterans.

## Field cage method

The cage trial was conducted to circumvent some of the unavoidable overlaps of populations faced in the field trial. The caged grasshoppers in particular represented a cross section of the species encountered at Hurso. Mixed species and ages were introduced into 20 cm diameter and 50 cm high cylindrical cages

(Tessema and Muinamia, 2001). The cages were spaced at 15 m to 20 m distances and were placed on green patches of grass so that the open bottom of the cages allowed the insect's access to fresh food supply. Five to ten insects of mixed species and ages were introduced to each cage covered with a muslin sleeve tied with rubber band around the top. The spray was directed at the cages, the drift passing through the muslin mesh and deposited on the insect and the grass at the base of the cage. Oil sensitive papers placed inside and outside the cages and sprayed with the insecticides showed no significant differences in the number of spray droplets. The results of insecticides tested in the field cage method are shown in Table 5.

Table 5. Percentage mortality of grasshoppers exposed to ULV insecticides sprayed in field cages (Tessema and Muninamia, 2001).

| Product | Percent mortality at different periods after spray | | |
|---|---|---|---|
| | 6 hours | 24 hours | Total |
| Sumicombi-Alpha 50% ULV | 95 | 05 | 100 |
| Nurell D | 85 | 15 | 100 |
| Reldan | 73 | 20 | 93 |
| Dursban | 66 | 22 | 88 |
| Carbosulfan | 93 | - | 93 |
| Fipronil 10 | 96 | 04 | 100 |
| Fenitrothion | 100 | - | 100 |
| Untreated check | 0 | 0 | 0 |

# African armyworm

## Chemical control

### Field evaluation of insecticides

The efficacy of Cyhalone (cyhalothrine) 4% ULV and Selecron (profenofos Q) 720 EC were evaluated against the African armyworm larvae at two sites in Jabi Tehnan district in the Amhara Regional State during the 2001 rainy season. Cyhalone 4% ULV was applied at the rate of 1 lt a.i/ha and Selecron 720 EC at 0.720 lt a.i/ha. The two standard insecticides used for comparison were fenitrothion 96% ULV and malathion 50 % EC applied at the rates of one liter and two liters per hectare, respectively (Tessema et al., 2001). The experimental design was a randomized complete block with five replications. The plot size was 10 m x 10 m and the spacing between plots was 3 m. The trial was conducted on flat and fallow terrain with mixed vegetation comprising grass

and broad leaf weeds. Micro–ULVA and knapsack sprayers were used for the application of the insecticides, depending on the formulation of the insecticides. Pre-and post-spray counts of the armyworm larvae were taken in each plot. The data from fenitrothion sprayed plot was rejected on account of enough replication. Post spray assessment was carried out 24 hours after application. However, larvae were already dying within three to six hours following spray applications, which meant that all of the three insecticides were fast acting compared with the control plots (Table 6). There were significant differences in the populations of larvae before and after insecticide applications regardless of formulation or mode of action. There were no significant differences among the insecticides tested. The two products tested performed equal to or better (in terms of visual assessment) than Malathion, e.g. in speed of kill and mortality counts (Tessema et al., 2001).

Table 6. Pre- and Post- spray counts of the African armyworm larvae (Tessema et al., 2001).

| Treatments | Pre-spray count | | Post-spray count | |
|---|---|---|---|---|
| | Dead | Live | Dead | Live |
| Cyhalone 4% ULV | 5.6 | 23.0 | 36.6 | 5.4 |
| Selecron 250 EC | 3.6 | 48.4 | 37.8 | 1.0 |
| Malathion 50% EC | 1.4 | 45.0 | 41.0 | 1.8 |
| Untreated check | 4.0 | 52.8 | 7.8 | 32.0 |

## Field evaluation of turex (*Bacillus thuringiensis)*

Bio-pesticides are considered as suitable alternatives for the control of agricultural pests. Among the bio-pesticides available in the market, *Bacillus thuringiensis* (commonly known as *Bt*) is considered as one of the most widely used bio-pesticides for the control of agricultural pests, particularly Lepidoptera larvae. This field trial was conducted in northern Ethiopia, in Kombolcha town, Kalu district in the Amhara region to evaluate the efficacy of Turex (*Bt*) against the African armyworm larvae during the beginning of the 2006 rainy season. The treatments tested were Turex® 50% WP (*Bacillus thuringiensis*), Sevin (carbaryl) 85% WP, which is the most widely used formulation in the area for armyworm control, and an untreated check. Turex® was applied at the rate of 300 g/ha, and carbaryl at 1.5 kg/ha. Larval stages at the time of treatment ranges from 4-5 instars (DLCO-EA, 2006b). The experimental design was a randomized complete block with three replications. The plot size was 10 m x 10 m and the spacing between plots and replications was 5 m. Different species of grasses were the dominant vegetation in the study site. The treatments were applied using Knapsack sprayers. Pre-spray counts of the armyworm larvae were taken just before application using 50 cm x 50 cm quadrant. Post-spray

counts were taken 24 hr and 48 hr after application. The results of armyworm larvae counts are shown in Table 7. The field trial seemed to be promising; however, further field work is required in order to make definite conclusions.

Table 7. Pre-and post-spray counts of armyworm larvae in Kombolcha (DLCO – EA, 2006b).

| Treatments | Pre- spray count | | Post-spray count after | | | |
|---|---|---|---|---|---|---|
| | Live | Dead | 24 hrs | | 48 hrs | |
| | | | Live | Dead | Alive | Dead |
| *B. thuringiensis* | 8.7 | 0.3 | 3.3 | 1 | 18 | 3.7 |
| Carbaryl 85% WP | 16 | 0 | 2.7 | 31.3 | 3 | 33.7 |
| Untreated check | 1.3 | 0 | 16.3 | 2 | 13.7 | 0.7 |

# Research on bird pest

## Basic study

The preliminary survey on bird pests conducted in Holetta, Denbi, Nazreth and Dukem areas indicated that weaver birds and pigeons on cereals and pulses, canary birds on brassica species and sunflower and mouse birds and starlings on plum, peach and grape are common pests (Table 8).

Table 8. Common bird pests recorded on different crops in the field (Abebe, 1986).

| Crops | Bird pest species | |
|---|---|---|
| | Common name | Scientific name |
| Wheat | Red bishop | *Euplectus franciscanus* |
| | Village weaver | *Ploceus cucolatus* |
| Sorghum | Red billed quelea | *Quelea quelea* |
| *Brassica* spp. | Yellow fronted Canary | Serinus mozambicus |
| | specked pigeon | *Columba guinea* |
| Sunflower | Yellow fronted Canary | *Serinus mozambicus* |
| Faba bean | Baglafecht weaver | *P. baglafecht* |
| | Speckled mouse bird | *Corvus striatus* |
| Grape | Speckled mouse bird | *C. striatus* |
| | Blue- eared glossy starlings | *Lamprotornis chalybatus* |
| Peach | Speckled mouse bird | *C. striatus* |
| Plum | Speckled mouse bird | *C. striatus* |

# Control measures

The efficacy of an aerial application of cyanox-50 (cyanophos 50% ULV) at the rate of 2 lt/ha was evaluated for the control of quelea birds (*Quelea quelea*) at

five separate roosting sites in the Central Rift Valley and nearby localities in the North Shoa of the Amhara Region. The results showed significant differences in mean bird counts between pre-treatment and post-treatment populations within each site (Table 9). The study confirmed that cyanox-L50 (cyanophos 50% ULV) when aerially applied against roosting birds is effective in reducing quelea population. It can therefore be considered as an effective complement to other avicides that are currently used for quelea control (Ndege and Gizachew, 2004). The established control technique for quelea birds involves the spraying of an avicide (Queleatox) against roosts and breeding colonies using fixed wing aircraft. This technique was successfully used in Ethiopia for over 25 years and millions of birds have been killed annually. Regardless of the numbers killed, the intensity of quelea problem has been increasing from time to time in different parts of the country. The results of the control operations for the past 10 years are presented in Table 10.

Table 9. Cumulative bird counts before and after aerial application of cyanophos 50% ULV (Ndege and Gizachew, 2004).

| **Locality** | **Time of bird census** | | | |
|---|---|---|---|---|
| | **Pre -spray** | **24 h** | **48 h** | **72 h** |
| Abay Negeso | 550,000 | 30,000 | 9,750 | 5,000 |
| Golbe | 1,300,000 | $28{,}580^{000}$ | 18,880 | 9,370 |
| Tebela | 521,810 | $147{,}630^{000}$ | 31,400 | 22,115 |
| Shekla | 500,000 | $11{,}800^{000}$ | 3,750 | 1,780 |
| Shoa Robit | 240,000 | $2{,}500^{000}$ | 1,250 | 1,000 |

Table 10. Quelea bird control operations conducted in Ethiopia from 1996- 2006.

| **Year** | **Bird population ($10^6$)** | **Roosting site treated (ha)** | **Avicide used (Liters)** | **Results (% kill)** |
|---|---|---|---|---|
| 1996 | 111.9 | 2787 | 5575 | 95.2 |
| 1997 | 97.2 | 1813 | 3635 | 94.5 |
| 1998 | 58.8 | 1385 | 2770 | 97.4 |
| 1999 | 73.3 | 1790 | 3590 | 95.6 |
| 2001 | 30.37 | 1163 | 2325 | 93.1 |
| 2002 | 41.18 | 1632 | 3270 | 95.9 |
| 2003 | 38.84 | 1903 | 3805 | 97.2 |
| 2004 | 20.7 | 619 | 1235 | 96.9 |
| 2005 | 12.86 | 580 | 1175 | 96.3 |
| 2006 | 53.75 | 1727 | 3455 | 96.0 |

Source: MOARD, Crop Protection Department Annual report 1996-2006.

# Rodents

## Rodent pests recorded

Major rodent pests of crops recorded in the country are listed in Table 11.

Table 11. Rodent species recorded in Ethiopia (Merid, 1988).

| Common Name | Scientific Name | Pest Status |
|---|---|---|
| Roof rat | *Rattus rattus* | Storage pest |
| Multimamate rat | *Praomys erythrolocus* | Field and storage |
| | *P. albipes* | Field and storage |
| Unstriped grass rat | *Arvicanthus abyssinicus* | Field crop pest |
| Field rat | *A. dembeensis* | Field crop pest |
| African mole rat/ roof rat | *Tachyoryctes splendens* | Root crop pest |
| Cane rat | *Thryanomys swinderianus* | Field crop pest |
| | *T. gregarianus* | Field and storage |
| Porcupine | *Histrix cristata* | Root crop pest |
| Zebra/ striped grass mouse | *Lemniscomys striatus* | Field crop pest |
| Savanna gerbil | *Tatera robusta* | Field crop pest |

# Basic studies

## African mole rat (*Tachyoryctes splendens*)

Surveys of the African mole rat damage were conducted in eight woredas of West Shoa and Sidama Zones. Estimated mole rat damage to enset plants is shown in Table 12. Analysis of mole mound density showed an average of 5 mole hills on each farm in the surveyed areas, and the highest number is 9.3 mole mounds in Fiseha Genet woreda (Table 13). In some areas like Areka in Wolayita area mole damage has been observed without any indication of mole hill in the farm. It was also estimated that an average of 0.80% damage was recorded in the visited areas. It was observed that enset damage was severe on seedlings in nurseries and on young newly transplanted enset plants less than two years old. Damage to matured enset plants above 5 years is low and the plant can tolerate damage and can survive if control measure is timely (Merid and Alemayehu, 1992). Comparing damage levels of the three awrajas, the highest was recorded in Dumarso district where inter-cropping of enset with coffee, sugarcane and sweet potato is common. Clean enset farms are mostly free of mole damage while unweeded farms particularly with *Digitaria* spp. and *Cynodon dactylon* grass were highly infested (Merid and Alemayehu, 1992).

Table 12. Enset farm areas and estimated mole rat damage in some Woredas of West Shoa and Sidamo Administrative regions (Merid and Alemayehu, 1992).

| Woreda | Farm Area | Plant/$m^2$ | Mean total plants | Mean Damage |
|---|---|---|---|---|
| Konteb | 7499.15 | 2.3 | 3260.5 | 4.56 |
| Limu | 2334.65 | 1.5 | 1556.43 | 3.42 |
| Angacha | 2220.53 | 1.6 | 1387.83 | 6.76 |
| Damota | 2330.61 | 2.7 | 863.19 | 7.51 |
| Areka | 5164.44 | 3 | 1721.48 | 5.15 |
| Dumarso | 3699.33 | 1.5 | 2466.22 | 65.6 |
| Fiseha Genet | 8259.43 | 2.4 | 3441.43 | 22.37 |
| Bule | 12289.23 | 2.7 | 4551.568 | 37.78 |
| Total | 341086.08 | 17.72 | 19,248.65 | 153.15 |
| Mean | 5328.36 | 2.215 | 2405.58 | 19.14 |

Table 13. Relationship of mole mound density to damage in survey areas (Merid and Alemayehu, 1992).

| Area (Woreda) | Mole Mound | Percent Damage |
|---|---|---|
| Konteb | 4.1 | 0.14 |
| Limu | 5.6 | 0.22 |
| Angacha | 4.3 | 0.48 |
| Areka | 2.2 | 0.29 |
| Damota | 3.4 | 0.87 |
| Fiseha Genet | 9.3 | 0.65 |
| Dumarso | 5.3 | 2.66 |
| Bule | 6.7 | 0.83 |
| Total | 14.5 | 6.14 |
| Mean | 5.19 | 0.7675 |

Survey of mole rat damage at Cheleleka plantation indicated heavy damage. Out of 12500 *Eucalyptus globulus* trees planted on 5 ha, 16% was damaged by the mole rat (Table 14).

Table 14. African mole rat damage to *E. globulus* in Cheleleka forest (Merid & Alemayehu, 1992).

| Block No. | Plants/ha | Plants damage/ha | Percent damage/ha |
|---|---|---|---|
| 1 | 2500 | 394 | 15.76 |
| 2 | 2500 | 386 | 15.44 |
| 3 | 2500 | 420 | 16.80 |
| 4 | 2500 | 478 | 19.12 |
| 5 | 2500 | 366 | 14.64 |
| TOTAL | 12500 | 2044 | 81.76 |
| Mean | 2500 | 408.8 | 16.35 |

*E. globulus* seedlings at nursery and young plants below 3 years old were found to be particularly susceptible to mole rat damage (Merid and Alemayehu, 1992). Mole rat survey conducted at Debre Zeit Research Center revealed that forage crops such as alfalfa (*Medicago sativa*) and rhodes grass (*Chloris gayana*) were highly threatened. An average of 1-2 mole rat mounds were counted in each square meter. In addition to plant damage, the mole rats construct mounds which were affecting the irrigation system (Merid and Alemayehu, 1993).

Field evaluation of four poisons against the mole rat revealed that zinc phosphide treated carrot or potato and aluminum phosphide treated carrot or potato and aluminum phosphide tablets resulted in promising control. The current study was conducted in the dry months at limited forestry sites. Hence, large-scale work at different seasons and vegetation zones is necessary to come up with efficient mole rat control methods (Merid and Alemayehu, 1993).

# Control measures

## The toxicity of four anticoagulants to the field rat

The efficacy of four anticoagulant rodenticides, viz. coumatetralyl, chlorophacinone + sulfaquinoxaline, bromadiolone and brodifacoum were evaluated under choice and no-choice regimes in the laboratory against the common field rat, *Arvicanthis abyssinicus*. The result indicated that 100% mortality in both sexes occurred from 5-12, 6-12, 5-15, 5-14 and 8-10 days for coumatetralyl, bromadiolone, brodifacoum (0.002%), brodifacoum (0.005%) and chlorophacinone + sulfaquinoxaline, respectively (Table 15) (Merid and Alemayehu, 1993). Results indicated that all the anticoagulants tested were satisfactory since they resulted in 100% mortality in less than 16 days (Merid and Alemayehu, 1993).

Acceptance test results of wheat-based anticoagulants with their alternative plain baits are indicated in Table 16 (Merid and Alemayehu, 1993). Differences between sexes were not significant and hence combined percentage acceptance data were analyzed. The test results showed that the acceptance of all poison baits was significantly lower than the plain baits ($P<0.01$). The acceptance of bromadiolone was the highest when compared with brodifacoum, coumatetalyl, and chlorophacinone + sulfaquinoxaline (Table 16). However, the differences in the percentage of acceptance among the means for brodifacoum, coumatetralyl, and chlorophacinone + sulfaquinoxaline were not significant. Similar to the wheat-based poison baits, acceptance of coumatetralyl liquid bait was significantly lower than the alternative non-poisoned water bait. However, there was not significant difference in acceptance of coumatetralyl liquid bait between the male and female rats.

Table 15. Toxicity of four anticoagulants against *A. abyssinicus* in a no-choice feeding test (after Merid and Alemayehu, 1993).

| Treatment | Days fed | Sex | Mortality | Dose 1 | Dose 2 | Days to death |
|---|---|---|---|---|---|---|
| Coumatetralyl | 2 | M | 5/10 | 40.8 | 37.9 | 6.8 |
| | | F | 7/10 | 39.5 | 37.4 | 7.6 |
| | 4 | M | 9/10 | 37.8 | 38.3 | 8.8 |
| | | F | 6/10 | 44.0 | 42.3 | 5.3 |
| | 6 | M | 10/10 | 31.4 | - | 8.4 |
| | | F | 10/10 | 30.5 | - | 7.8 |
| Chlorofacinone + sulfaquinoxaline | 5 | M | 4/5 | 5.3 | 3.9 | - |
| | | F | 5/5 | 4.9 | 12.4 | - |
| Bromdiolone | 2 | M | 6/10 | 5.0 | 5.0 | 8.0 |
| | | F | 7/10 | 5.5 | 7.6 | 8.7 |
| | 4 | M | 8/10 | 5.2 | 5.6 | 7.8 |
| | | F | 9/10 | 4.7 | 5.7 | 6.7 |
| | 6 | M | 10/10 | 4.7 | - | 8.3 |
| Brodifacoum (0.002%) | 1 | M | 4/6 | 1.7 | 1.4 | 7.0 |
| | | F | 3/6 | .4 | 1.6 | 8.7 |
| | 2 | M | 6/6 | 1.5 | - | 7.8 |
| | | F | 5/6 | 9.0 | 1.4 | 7.0 |
| | 4 | M | 5/6 | 1.7 | 0.9 | 10.0 |
| | | F | 6/6 | 1.8 | - | 10.0 |
| | 6 | M | 6/6 | 6.6 | - | 9.5 |
| | | F | 6/6 | 7.0 | - | 11.0 |
| Brodifacoum (0.005%) | 1 | M | 10/10 | 4.4 | - | 8.6 |
| | | F | 9/10 | 5.5 | 4.4 | 7.2 |
| | 2 | M | 10/10 | 3.4 | - | 10.5 |
| | | F | 10/10 | 4.4 | - | 9.2 |

Dose 1 and Dose 2 refer to lethal and sub-lethal dosage, respectively.

Table 16. Mean body weight, duration of test, mean daily percentage acceptance of baits, and mortality of *A. abyssinicus* in a -choice test (Merid and Alemayehu, 1993).

| Treatment | Body weight (g) | Duration (days) | Acceptance | | Mortality |
|---|---|---|---|---|---|
| | | | Poison | Plain | |
| Coumatetralyl (0.0375) | 85.6 | 15 | 14.9 | 85.1 | 16/20 |
| Chlorofacinone (0.006%)+ Sulfaquinoxaline (0.019%) | 90.2 | 15 | 8.6 | 91.4 | 16/20 |
| Bromadiolone (0.005%) | 83.5 | 15 | 33.5 | 66.5 | 20/20 |
| Brodifacoum (0.005%) | 89.7 | 7 | 18.9 | 81.0 | 18/20 |

Except for bromadiolone and liquid coumatetralyl, the acceptance of each test poison was lower than the USEPA acceptance threshold level of 33%. Jackson (1986) also reported that acceptance for most first generation anticoagulants is below this threshold and mortality of most of the test animals was

unsatisfactory. The test results showed that the acceptance of all of the poison baits was significantly lower than the plain baits ($P<0.01$).

## Comparison of poison baits and fumigation tablets against the African mole rat

Active mole rat hill counts during pre- and post-treatment census in poison treated blocks are summarized in Tables 17 and 18. zinc phosphide 4% treated potato and carrot, aluminum phosphide 57% tablet and flocoumaten wax blocks 0.005% gave an average of 56.6, 70, 72 and 16% control, respectively (Table 18). The analysis of variance revealed that the differences in the mean percentage of control among treatments were significant at 5% level ($F = 26.28$, $df_I = 3$, $df_2 = 12$). However, LSD test confirmed that only 0.005% flocoumafen wax block was different from all of the other treatments at 1% and 5% level, and this treatment was found to give the lowest percentage of control success among all of the other treatments (Alemayehu and Million, 1994). Most wax blocks were found mouldy during the opening of the prod-holes due to the underground moisture. The efficacy of flocoumafen wax block was lowest due to the fungal activity on the poison before the mole rats start to feed on them. The active ingredient in flocoumafen wax block is 0.005% flocoumafen. The researchers did not have the information on the food content and other attractants present in the flocoumafen wax block. Thus, they were unable to compare it with 4% zinc phosphide treated potato and carrot based on taste and odour of the food ingredients present in them (Alemayehu and Million, 1994).

Table 17. Results of poison baits and a fumigation tablet against mole rat at Cheleleka forest plantation (Alemayehu and Million, 1994).

Active mole rat hills during pre and post-treatment census

| **Treatments** | **Pre-treatment mean*** | **Post-treatment Mean*** |
|---|---|---|
| 4% Zinc phosphide treated potato | 9.6 | 4.2 |
| 4% Zinc phosphide treated carrot | 10 | 3 |
| 57% Aluminum phosphide | 10 | 2.8 |
| 0.005% Flocoumafen wax block | 10 | 3.4 |

*Mean of 5 reps

Table 18. Percentage of control success of poison baits and fumigation table against mole rat at Cheleleka forest plantation (Alemayehu and Million, 1994).

**Active mole rat hills during pre-treatment count**

| Treatments | Mean* |
|---|---|
| 4% Zinc phosphide treated potato | 56.6a |
| 4% Zinc phosphide treated carrot | 70.0a |
| 57% Aluminum phosphide | 72.0a |
| 0.005% Flocoumafen wax block | 16.0b |
| SE | 4.65 |
| LSD 0.05% | 10.13 |
| LSD 0.01% | 14.21 |

* = mean of five replications

Means followed by a common letter are not significantly different from each other at P = 0.01 level of significance. ANOVA based on Arc sine transformed values.

It appears that cost-effective results could be obtained by using the cheaper and safer poison baits 4% zinc phosphide treated potato and 4% zinc phosphide treated carrot during the first application, and to use 57% aluminum phosphide tablets during the second application of treatment. On the other hand, it has been reported that 57% aluminum phosphide tablets have not always been successful, probably because of soil texture and burrow length. This control method is particularly suitable in damp and consolidated rodent burrows (Alemayehu and Million, 1994).

## Integrated rodent management

Village rat control campaign was carried out in Ketto, one of the settlements in Western Wollega zone. Preliminary survey before the control operation showed an average of 30-40 rats in each house. Post-harvest damage from rodents in big stores was estimated to be 76930 kgs. In addition to crop damage, many instances of sheep with their tails bitten off were observed (Merid, 1988). In Ethiopia, about 15 of approximately 57 rodent species known are economically important. At Ketto settlement, the roof rat, *Rattus rattus* and striped mice, *Leminoscomys striatus* were found to be common rodent species.

Acute toxicants, zinc phosphide, the double dose poison, Klerat pellet and kill traps were used in the control campaign. Three bait stations with 20-30 gram per station were used in each house. No take (nt), partial take (pt) and whole take (wt) were recorded for both rodenticides in each house for 21 days. The baits were replenished every 3 days and dead rats were recorded (Merid, 1988). About 3200 kg of 3% zinc phosphide was formulated and distributed to 10360 houses, 200-300 gms/house. The baits were applied on banana leaves during evenings and retrieved in the morning for seven days, after which 4000 kg of

klerat pellets were distributed to all villages. Kill traps amounting 2680 were distributed to all villages, 134 traps per village. Local farmers and settlers were organized into 240 rat control task forces. Each task force with 100 individuals was deployed to kill the rats and destroy the sources and harborages of rats in the village. In general, 99650 rats were killed in 10360 houses within nine weeks (Table 19). After the campaign, post treatment population census revealed that the rate of infestation was greatly reduced but there were still some rat infestations left in the village (Merid, 1988).

Table 19. Summery of rat control campaign in Ketto settlement areas (May 20- August 1988) (Merid, 1988).

| Village | No. of houses per village | Pre-treat. rat pop. per 20 houses per village | Rat damage | | Amount of poison | | No. of traps | No. of rats killed | Post-treat. rat pop. per 20 houses per village |
|---|---|---|---|---|---|---|---|---|---|
| | | | Stored Crops (kg) | No. of domestic animals bitten | Klerat (kg) | ZN3P2 (kg) | | | |
| 1 | 532 | 43 | 9680 | 11 | 200 | 120 | 134 | 4569 | 4 |
| 2 | 496 | 39 | 6280 | 22 | 200 | 120 | 134 | 9545 | 6 |
| 3 | 558 | 29 | 5420 | 17 | 200 | 170 | 134 | 5309 | 2 |
| 4 | 450 | 36 | 5361 | 16 | 200 | 170 | 134 | 5426 | 1 |
| 5 | 577 | 34 | 7495 | 14 | 200 | 150 | 134 | 9082 | 6 |
| 6 | 550 | 46 | 500 | 5 | 200 | 170 | 134 | 2580 | 8 |
| 7 | 466 | 37 | 6340 | 4 | 200 | 170 | 134 | 7060 | 7 |
| 8 | 422 | 28 | 230 | 23 | 200 | 170 | 134 | 5024 | 4 |
| 9 | 523 | 34 | 3481 | 2 | 200 | 170 | 134 | 1609 | 3 |
| 10 | 468 | 26 | 568 | 5 | 200 | 150 | 134 | 1819 | 2 |
| 11 | 515 | 38 | 396 | 1 | 200 | 170 | 134 | 9655 | 6 |
| 12 | 539 | 43 | 2493 | 0 | 200 | 170 | 134 | 9019 | 5 |
| 13 | 470 | 50 | 1146 | 6 | 200 | 170 | 134 | 2110 | 6 |
| 14 | 565 | 26 | 2496 | 4 | 200 | 170 | 134 | 7460 | 9 |
| 15 | 432 | 41 | 1486 | 3 | 200 | 150 | 134 | 2392 | 2 |
| 16 | 453 | 48 | 1426 | 7 | 200 | 150 | 134 | 2588 | 5 |
| 17 | 658 | 46 | 10380 | 14 | 200 | 150 | 134 | 3177 | 3 |
| 18 | 651 | 36 | 7646 | 11 | 200 | 210 | 134 | 1388 | 7 |
| 19 | 378 | 27 | 2642 | 12 | 200 | 150 | 134 | 3501 | 4 |
| 20 | 657 | 48 | 1463 | 5 | 200 | 170 | 134 | 4437 | 8 |
| Total | 10360 | 14200 | 76930 | 182 | 4000 | 3200 | 2680 | 99650 | 98 |

# Conclusion and recommendations

Out of very few studies conducted in the past several years, the following results could be used immediately:

- A bio-pesticide, *Metarhizium anisopliae* (Green Muscle) can be used for the control of locusts and grasshoppers in environmentally sensitive areas.
- Cyanophos 50% ULV (cyanox -50) can be used as an alternative for the control of quelea birds.

- Some bio-pesticides such as *Bacillus thuringiensis* (*Bt*) need to be further verified for the control of the African armyworms.
- Combined use of zinc-phosphate treated with carrot or potato and aluminum phosphate tablets (2 tables/hole) can be used to control mole damage in forestry plantations.

## Gaps and challenges

- No research on rodents and quelea birds is being conducted in any of the research centers in the country at present.
- Alternatives to chemical control of migratory pests and rodents are not adequately studied.
- The efficacy of traditional or indigenous bird control technique is not studied.
- The extent of losses caused by migratory and rodent pests have not been studied adequately.

## Prospects

- Agricultural research institutions, namely EIAR, regional agricultural research institutions (RARIs) and higher learning institutions (HLIs) need to include rodent and bird pest problems in their research programmes.
- The necessary financial support and resources should be alocated for migratory pest and rodent research programmes.
- Bio-pesticides and botanicals that have proved effective and safer to human health and the environment in other countries need to be introduced and tested.
- The entomopathogenic fungi that have been isolated in the country and provided promising results in laboratory bioassys should also be evaluated under field conditions in locust habitats.

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# Prevention of Accumulation of Obsolete Pesticides: Components of a Programme Aimed at Preventing Further Obsolete Pesticide Stocks in Ethiopia

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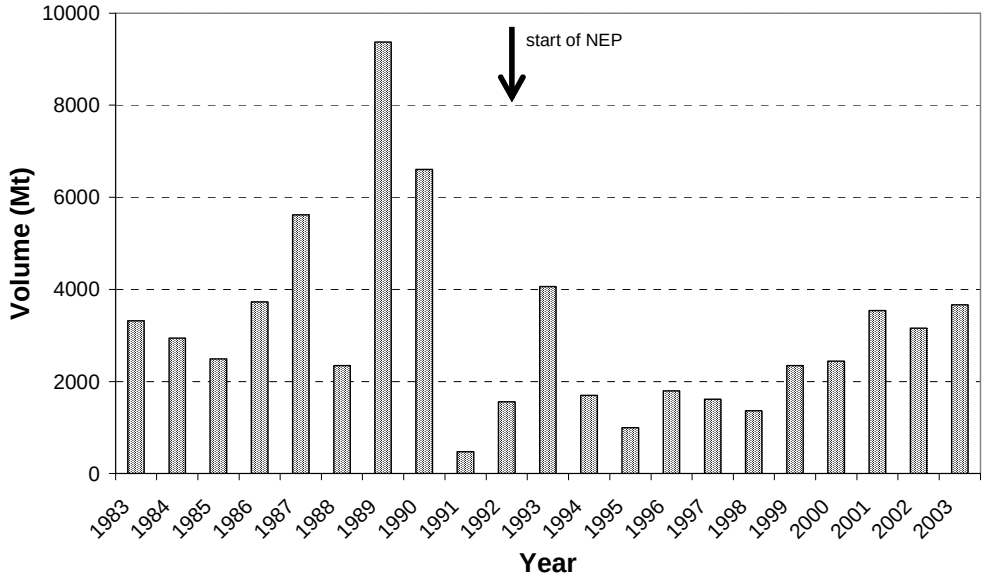
## Introduction

Chemical pest control has been widely used in Ethiopia for the control of migratory pests such as Desert Locusts, Armyworms and *Quelea* birds and in commercial farms for the control of many other pests. Moreover, the use of pesticide is still considered as the best method for the control of malarial transmitting mosquitoes. Pest control researches in the past focused on chemical control method and encouraged the use of pesticides. As a result, the country has been importing large quantities of pesticides over the past 40 years. Most of the pesticides used in Ethiopia are imported from Germany, Switzerland, England, Japan, Israel, Belgium, India and U.S.A.

Based on 1983-1993 data, Ethiopia's annual import of pesticides is estimated at more than 4,000 tones, worth approximately US $ 21 million (Gorden *et al*., 1995). The recent annual pesticide imports (average for 1994-2002) are estimated at about 1,800 tones valued at US $ 8 million (Tsedeke, 2003). The freeing of exchange rate and subsequent devaluation of the Ethiopian Birr, the liberalization of agricultural input market (which reduced the virtual monopoly position of the Agricultural Import and Supply Enterprise (AISE) for inputs distribution) and reforms of state farms and transformation of the same farms into market oriented business are the major causes for this significant decline of pesticide imports, compared to the former imports. However, a steady increase in the pesticide market occurred again with a total volume reaching above 3,000 tones in 2001 and 2003. The average compound annual growth rate in the national pesticide market from 1994 to 2003 was 16%, well above world average, which varied from 0 to 4% annually during the same period (van der Valk, 2004).

**Pesticide Import Volume in tones from 1983- 2003**




NEP : National Economic Policy
**Source:** (van der Valk, 2004).

Even though commercial farms are the major users of pesticides in Ethiopia, use by small farmers also appear to have increased because of the government's intensification drive (Tsedeke, 2003).

There is a growing fear that the "pesticide dependency syndrome" may soon catch up in the country, especially because of the current market oriented agriculture development and crop specialization programme. Farmers who are able to grow horticultural crops, especially vegetables are in the threshold of getting into the "pesticide treadmill", since the investment is more profitable than cereal agriculture. However, the unavailability of pesticides and their escalating costs, low level of know-how on their proper use, handling and storage by smallholder farmers, the hazard to human, animals, plants, natural enemies and beneficial insects, make the reliance on pesticides questionable.

## Pesticide related problems in the country

There have always been risks associated with pesticide use in different parts of the country. These include accidental spills, usually associated with pesticide mixing resulting in localized but severe environmental impacts. Applicator's intoxication due to pesticide spraying against the wind is a common phenomenon, as farmers usually do not use safety devises during application. Pesticide poisoning to humans and damage to non-target crops, natural

vegetation, natural enemies and beneficial insects (e.g. bees) and the environment could also occur in different areas as a result of using high dosage of pesticides and application of highly hazardous and broad – spectrum pesticides.

Although detailed data on hazards associated with pesticide use are lacking, various incidences of human and livestock poisonings have been reported in different parts of the country due to the improper use and storage of pesticides. According to a report of the Ethiopian Research Institute of Health (today Health and Nutrition Institute), poison cases due to DDT involving more than 500 hospitalized patients occurred in Addis Ababa on February 24, 1991. Studies conducted by the Desert Locust Control Organization for Eastern Africa (DLCO-EA) in Western Oromia in 1990 showed the presence of an appreciable level of organo-chlorine residues such as *DDT, HCH* and *Dieldrin* in human blood. A recent study in the state owned horticultural farms also revealed the incidence of respiratory impairment among some pesticide applicators. Damage to honeybees was similarly reported in 1994 in Tigray Region where an extensive aerial application of pesticides was undertaken against the invasion of armyworm. Pesticide resistance problems on state farms and mosquito resistance to *DDT* have also been reported.

High level of misuse and abuse of pesticides have been reported at different times in the country. For instance, the case study conducted in 2002 by the Safe Environment Group with smallholder farmers near Bahir Dar has revealed highly hazardous use and abuse of pesticides by resource-poor farmers growing cereals, legumes, vegetables and 'chat' leading to human and animal poisoning and concerns about residues in food. In another occasion, over 25,000 kilograms of highly toxic nematicide, *Aldicarb (Temik*), which was stolen from one of the state farms, was circulating on the black market all over the country. This pesticide was advertised by illegal traders for use against rodents by resource poor farmers and urban dwellers out of its purpose. Thirty hectares of cropland were destroyed in Arsi (Oromia Region) in 1999 as the result of misuse of *Chlordane*, a pesticide known as a persistent organic pollutant (POP).

Similarly, the large masses of unused obsolete pesticides (about 3,000 tons) accumulated over the last 40 years in the country have threatened the health of people and contaminated the environment due to leakage of chemicals from corroded or burst containers. The presence of obsolete stocks traded by illegal pesticide retailers for use in smallholder agriculture has exacerbated the misuse and abuse problems of pesticides in the country.

Related to the above situation, the Conceptual Framework of Externality with regard to pesticide damage cost and damage abatement expenses is summarized by Khan (2004) as follows :-

| Externality area/category | Damage cost | Damage abatement cost |
|---|---|---|
| **Human health** | | |
| Pesticide applicators | Fatalities, treatment cost | Blood samples monitoring cost, awareness campaigns, workdays loss |
| Irrigation and drinking water | Contamination of underground water resources | Residue monitoring, cost to get clean water |
| Industrial workers, distribution, storage and disposal | Acute/minor ailment cost, treatment cost, environmental degradation | Blood samples, monitoring cost, awareness campaigns, implementation of safety regulations, work days loss, incineration cost, skilled experts cost |
| **Pesticide residues** | | |
| Oil crops, vegetables, coffee | Pesticide poisoning, loss of foreign market | Residue monitoring, implementation of regulations |
| Irrigation and drinking water | Contamination of underground water resources | Residue monitoring, cost to get clean water |
| **Production externalities** | | |
| Pest resistance | Yield loss | Research and extension, more pesticide use cost |
| Domestic animal poisoning | Production loss, mortality and treatment cost | Awareness cost |
| Wild honeybee loss | Loss of honey and yield loss due to pollinator loss | Research to prove and prevent honey bee losses |
| **Environmental externalities** | | |
| Wildlife and birds | Loss of useful insects and birds fauna | Ecosystem analysis to restore natural balance |
| Loss in biodiversity | Stagnating or declining productivity | Ecosystem analysis to restore natural balance |
| Health and environmental monitoring | Health and environmental damages | Establishment of regular residue monitoring system |
| Public awareness campaign | Complexity to develop general recommendations | Campaign on safe and judicious use of pesticides |

## Disposal of obsolete pesticides

Strong measures have been taken by the government with the support of donor organizations to dispose off obsolete pesticides.

Different organizations have been responsible for the past accumulation of pesticides in the country. These include the Ministry of Agriculture and Rural

Development (MoARD), State Farms, Agricultural Inputs Supply Corporation (AISCO), now Agricultural Input Supply Enterprise (AISE), Agricultural Equipment and Services Enterprise, Ethiopian Seed Enterprise (ESE), Ministry of Public Health (MoH), Desert Locust Control Organization for Eastern Africa (DLCO-EA) and others. The largest share of obsolete pesticide stocks (56%) was under the responsibility of MoARD, followed by state farms (17%), state agricultural input companies (AISCO, AISE, ESE 15%), DLCO-EA (6%), MoH (4%) and others (1%), respectively.

The main factors that have contributed to the formation of the present stockpiles of obsolete pesticides in the country are the following:-

- Prolonged storage of pesticides in stores due to absence of pest outbreaks (e.g. Desert Locust) for which they are intended for;
- Inadequate store and poor stock management;
- Donations or purchases in excess of requirements without identification of the need;
- Importations of unsuitable products without prior identification of their efficacy; and
- Absence of proper pesticide legislation before 1990.

The total cost for safe removal of 1,500 tons of obsolete pesticide stocks from Ethiopia through the first phase (1999-2003) of the obsolete pesticide disposal project was US $ 3.6 million. The same or more amount of money would be required to dispose the remaining stocks (about 1,500 tons) accumulated in the country using a second phase project with donors support. The support of donors from the international community is essential for the implementation of such a huge, technically specific and costly programme. Based on the capacity built and fruitful experiences obtained from the first phase of the project and the external funds secured from the Governments of Belgium, Finland and Japan, the phase II prevention and disposal of obsolete pesticide stocks programme has been ongoing since the year 2003. The key components of the second phase are as follows:-

A. **Clean up** and **disposal** (disposal of 1,000 tones of obsolete pesticide stocks, disposal of contaminated soils, containers and buried pesticides);

B. **Capacity building** and **institutional strengthening** (building national capacity in various areas related to pesticide stock management, environmental monitoring and laboratory capacity); and

C. **Prevention** of further accumulation of obsolete pesticides.

## Prevention of further accumulation of obsolete pesticides

Disposal of obsolete pesticide stocks is not a long-lasting solution to obsolete pesticide problem; the most sustainable solution depends on proper implementation of the preventive measures. Therefore, the second phase of the project has given much emphasis to prevent further accumulation of similar pesticides by carrying out the following activities:-

- Strengthening pesticide registration and control;
- Improving pesticide management;
- Improving storage of pesticides;
- Strengthening laboratory capacity;
- Developing alternatives to chemical pest control including implementation of IPM; and
- Public awareness on obsolete pesticide problems and prevention measures.

## Strengthening pesticide registration and control

Recognizing the need to use relatively safe, locally effective and good quality pesticides that comply with international standards aiming at minimizing the adverse effects of pesticides to human beings, animals, plants and the environments the Ethiopian Government enacted pesticide legislation in 1990. The legislation, "Pesticide Registration and Control Council of State Special Decree No 20/1990" was drafted based on guidelines set by the Food and Agricultural Organization of the United Nations (FAO).

The Ministry of Agriculture and Rural Development (MoARD) was given the mandate to register and regulate pesticides in the country. To carry out this activity, pesticide registration experts and inspectors were assigned to the head quarter and to regions to enforce the regulation. In addition, over 1,000 crop protection experts, pesticide experts and development agents have been trained over the past six years on proper pesticide handling, safety, regulation and removal of obsolete pesticides and pesticide containers.

To support the pesticide registration and control scheme, the pesticide formulation and residue analysis laboratory of the MoARD has been upgraded with the necessary equipment with the support of the International Atomic Energy Agency (IAEA), the United Nations Development Programme (UNDP) and FAO.

Through the registration procedure at present, 162 pesticides have been registered for use in agriculture and for the control of household pests. Pesticide inspectors monitor import, usage and storage of pesticide and pesticide samples

are taken and analyzed at the pesticide laboratory to confirm that the product meets specifications. By implementing the regulatory mechanisms the import of unregistered pesticides and excess imports has been controlled.

The Basel, Rotterdam and Stockholm conventions have been ratified by the Ethiopian Government through the Environmental Protection Authority (EPA) to facilitate the implementation of the pesticide registration and control legislation of the country and the international policy instruments that deal with direct operational implications for pesticide management. Contrary to the original arrangement, since the ministerial reorganizations of early 2004, a new proclamation in pesticide registration and control was enacted in the same year (2004). Since then, pesticide registration and control in Ethiopia are being carried out by two Government bodies: the Crop Protection Department of MoARD and the Drug Administration and Control Authority (DACA).

However, the legal responsibility of the two bodies is not entirely clear, especially with respect to the types of pesticides that are to be registered by each body. The present situation can practically create a loophole for potential illegal pesticide traders. The definition of pesticide in the above two legislations is not similar. Moreover the definition of pesticide in the proclamation of DACA is no longer in accordance with international pesticide convention and code of conduct. Such condition and diversity of responsibility has resulted in inaccurate use of legal and technical words and differences in translations. Therefore, the following activities have to be carried out to strengthen the pesticide registration and regulation scheme in the country.

## Create one pesticide legislation authority

Without much doubt, it would be best to have one national body responsible for the evaluation and authorization of pesticides in the country. This will ensure the optimal use of the existing expertise. Moreover, it will be cheaper to operate and will avoid confusion for the private sector while reducing the risk of abuse.

Such a national pesticide registration should cover all pesticides that are distributed in the country according to the internationally accepted definition of pesticide as provided in the revised version of the International Code of Conduct on the Distribution and Use of Pesticides (FAO, 2003), which was adopted by all FAO Member States, including Ethiopia. Therefore, recognizing the need for compulsory registration of all pesticides under one legislative control authority, the Crop Protection Department of the MoARD recently drafted a national pesticide proclamation to be forwarded to Parliament for approval.

## Develop proper evaluation procedures and acceptability criteria

Proper procedures should be developed for evaluation of registration dossiers submitted by the registrant. Moreover, nationally applicable criteria for the acceptability of pesticides in Ethiopia need to be set.

## Increase synergies between enforcement bodies

There is an urgent need to increase and improve the coordination and cooperation between the various government bodies responsible for pesticide related inspection and control activities to combat illegal pesticide trading activity. Such organizations include Ethiopian Customs Authority, National Bank of Ethiopia, Ministry of Trade and Industry, Police and legal personnel.

## Build technical capacity for enforcement

It is important to provide trainings to personnel involved in enforcement in various Government bodies in order to build the technical capacity of the concerned staff.

## Collection and analysis of pesticide distribution, sale and use data

Detailed knowledge of the quantities and types of pesticides imported, formulated, distributed, sold and used in Ethiopia is necessary to have early warning of the creation of new pesticide stocks. Therefore, there is a need to develop a national pesticide statistics collection system. There are basically two ways of developing the statistical database. This are:

**A cradle-to-grave approach:** In this approach, individual consignment of pesticides imported or locally formulated is followed throughout its life. This provides the most comprehensive form of data collection and allows detailed monitoring. However, such system requires considerable staff time for data input and record inspections as the stakeholders register and store.

**A cradle to old age approach:** In this approach, data on import formulation and major distribution are complete while figures for retail and consumption are only partially available. The life cycle of pesticides is then deduced from the data rather than exactly known, as would be the case in the first approach. This approach is much easier and cheaper to administer. The same approach can be chosen, if pesticide flows in the country are to be known in a more general way (e.g. for policy development and early warning of potential problems).

# Improved pesticide management

## Pesticides for migratory pest control

### Armyworm

The two main reasons why much insecticide intended for armyworm control become obsolete are:

- Difficulties in redistribution of pesticides for armyworm control, and
- Overestimation of security stocks required to face armyworm outbreaks.

A major bottleneck in pre-positioning of insecticides for armyworm control is the difficulty to predict armyworm outbreak in time and space. Warning times based on the national trapping and DLCO-EA international forecasts are generally too short (it would give a warning of one month (maximum) to influence pesticide pre-positioning on a national scale). The security stock of about 300,000 litres, which is necessary, is more than 4 times the annual insecticide consumption for armyworm. Therefore, to overcome the above-mentioned problems the following recommendations were recently made (van der Valk, 2004):

- To bring pesticide stocks under federal administration control to allow optimal and effective armyworm control;
- To improve pesticide need estimates for armyworm control in Ethiopia by employing historical risk assessment of armyworm outbreaks; and
- To assess the effectiveness of alternative armyworm control techniques.

### Desert locust

Contingency planning is one of the strategies to improve the management of pesticides in locust control. A contingency plan developed within the framework of the FAO EMPRES Central Region Programme include control requirements for invading swarms and for first/second generation hoppers, logistical constraints, choice of insecticides, costs of strategically stocking insecticides at one or more locations (including quality control), stock rotation and upgrading and maintaining of storage facilities and costs and constraints of operating a “Pesticide Bank System”. Such a plan is important to launch effective control operation and will contribute to reduce the risk for the creation of new obsolete stocks.

## Grain-eating birds

Pesticides destined for bird control have not contributed much to the obsolete pesticide stocks in Ethiopia as a limited amount (on average 2,000 litres) of avicides is being used annually.

## Improved storage of pesticides

There is a pressing need for improved storage facilities for pesticides in the country to ensure safe storage of pesticides. Almost all of the pesticide stores in the country, used for storage of pesticides destined for the control of migratory and non-migratory pests are old, substandard and over-stocked. The metallic stores that were constructed many years ago are not ideal for the storage of pesticides as the inside temperature rises several degrees higher than the outside temperature even under normal weather conditions. They are without proper air ventilations and thus pesticide vapours build up to high toxic levels. Some stores are also built in lower grounds, get flooded easily, and unfortunately lack concrete floors. Such poor storage conditions invariably accelerate deterioration of pesticides way before their expiry dates. Due to poor storage, pesticides like *Malathion* can be converted to more hazardous *Iso-malathion* and *Diazinone* to the more hazardous *Sulfotep.* Such incidences contributed to the accumulation of huge quantities of obsolete pesticides in the country.

In view of the above unacceptable storage conditions and as part of national strategy for an effective management of migratory pests and to ensure that further obsolete stocks are not accumulated, the Prevention and Disposal of Obsolete Pesticide Stocks project has planned to construct new stores according to FAO guidelines in 4 regions at strategic locations. Moreover, as part of obsolete pesticide prevention strategy, pesticide storage should also be regulated and integrated with pesticide registration. Unless a minimum required storage criterion is respected by specific user groups, sale and use of pesticides should not be authorized to these groups.

## Proper storage and record keeping

In addition to improving infrastructure for pesticide storage, storage practices should be regulated. This includes proper container stocking practices, stock planning (e.g. *first–in, first-o*ut principle), safety and emergency procedures, decontamination, disposal, record keeper and reporting.

## Pesticide quality control in storage

Regular pesticide quality monitoring is an important aspect of proper pesticide storage, so that farmers and other users get products that are of good standard. Regular monitoring will also help identify batches of pesticides that could become obsolete in the near future, allowing early intervention. However,

monitoring pesticide quality all over the country is a difficult task, because of high costs, limited laboratory capacity and logistical difficulties and transporting pesticides to Addis Ababa. An alternative less expensive monitoring can be achieved and the pesticide quality can be monitored through:

- Stricter registration criteria;
- Controlled quality assessment system (to evaluate pesticide stability under local conditions); and
- Spot-checks whenever deemed necessary.

### Training of store-keepers

Training of storekeepers is an essential element of the judicious storage of pesticides. In view of this, a Training of Trainers (ToT) course in responsible storage of pesticides was provided to 14 trainees from Regional Bureaus of Agriculture and Rural Development on November 2004. Refresher/Evaluation course was given for the same trainees and another ToT course took place in July 2005.

### Using pesticides beyond their shelf-life

The normal shelf life of most pesticides under "normal" conditions is two years. However, after this deadline, pesticides do not necessarily become obsolete and could still be used from the crop protection point of view.

As long as the physical quality of the pesticide is still acceptable and toxic metabolites have not been formed in excess of standard, the pesticide can be used, even with considerably lower active ingredient concentrations. It may be necessary, however, to adjust the application rates so that the active ingredient rates correspond with the recommended rates of the original formulation.

### Reformulating substandard pesticides

If a pesticide quality does not comply with the registration standards any more, reformulation is an option. There is a possibility to carry out local reformulation of certain pesticides possibly using the facilities at the pesticide formulation plant of Adami-Tulu.

## Collection of empty containers

### Deposit based container collection scheme

Under such scheme, a deposit is paid on top of the pesticide, which will be reimbursed when the container is brought back to the supplier. Such system is costly to administer, and will increase the retail costs of pesticides. The deposit system may be cost-effective, however, if the empty containers can be

collected, cleaned and re-used for new pesticides at a cost less than using entirely new containers. This may be applicable to the locally formulated pesticides in Ethiopia.

A collection system can be run entirely by the private sector or by joint government/private sector partnership.

## Container collection scheme for large–scale users

Irrespective of the introduction of a deposit based collection system, large-scale pesticide users (e.g. 200 kg or litre per year) should be obliged by law to return empty containers to dedicated collection points for recycling or disposal.

## Strengthening laboratory capacity

There is a need to create an operational capacity for pesticide quality control and residue analysis. The midterm (e.g. in 4-6 years) should see the creation of international accredited pesticide quality control and pesticide analysis laboratory.

## Developing alternatives to chemical pest control

Among different alternative strategies, Integrated Pest Management (IPM) is the main one, which is useful to keep the pesticide use to a minimum and prevent further accumulation of obsolete pesticides in the country.

In view of this, the obsolete pesticides project has initiated an IPM-Farmers' Field School (FFS) with cotton crop in three major cotton growing Woredas (Districts) in the Southern Nations, Nationalities and Peoples Region (SNNPR). Prior to the launching of IPM-FFS programme in the region, two personnel were sent abroad in July 2005 to gain first hand experience on the implementation of FFS and the training of IPM facilitators.

## Public awareness on obsolete pesticides and prevention measures

Enforcement of pesticide regulatory programme can only be successful if there is awareness among the general public and regulated community. Awareness creation on the problem of obsolete pesticides, prevention measures to be taken, and informing the public about the on-going initiatives is one of the important activities to be carried out under the Phase-II of the “obsolete pesticides project”.

With this in view, a number of awareness raising seminars in relation to obsolete pesticides have been completed between 2004 and 2006, targeting

research institutions, universities, ambassadors and several officials from different governments, non-governmental and international organizations.

## Roles of NGOs in the disposal and prevention of obsolete pesticides

The actual presence of NGOs in rural development contributes to enhance the livelihood and socio-economics of smallholders. In this regard, NGOs should actively involve themselves in the efforts to the remedy of the problem in one-way or another. Their prime mission and vision -working for the betterment of the rural poor- directly calls their efforts to be coordinated in the activities of disposing and preventing future accumulation of obsolete pesticides.

In general, it is believed that the problem of obsolete pesticides can only be left to professionals and specialized institutes. Due to its repercussions on people's health, on the environment, on future crop farming etc., it is a cause for public concern and calls for every individual to do his/her share.

The involvement of NGOs is highly significant in developing ways and means of prevention activities. It is believed strongly that the introduction of IPM in agriculture should be taken as a cornerstone of agricultural production, which entails pesticides as a last resort. NGOs, as they are working at a grass root level, should encourage farmers to use their indigenous traditional knowledge to control pests and meanwhile test their efficiency and efficacy. Moreover NGOs can assist the government in providing feedback regarding the costs and benefits of using external inputs and marketing functions.

It is believed that NGOs and the whole civil society need to complement these efforts in order to make it efficient and long lasting.

## Some activities to be carried out by NGOs

Normally, there are many NGOs operating throughout the country. Not all may be involved in agricultural and/or environmental activities. However, the problem of obsolete pesticides and empty containers is not only an agricultural problem. It is also related to human health, water, utensils and the general environment. Hence, it calls for the concerted effort of every NGO in rural and urban areas. The contribution of every NGO could be smaller or bigger. What is needed is overall participation and engagement.

Some of the activities for NGOs are the following:

**1. Awareness creation**

As NGOs are working at grass root levels due to the nature of their activity, access to community is easier and they should actively participate in informing the public. NGOs can constantly create mass awareness regarding the issue of obsolete pesticides and the proposed measures to be taken at local, community and household levels.

1.1. **Self-awareness**

When NGOs themselves are properly informed about the issues linked to obsolete pesticides, they will be able to create proper awareness among others.

1.2. **Informing others**

Provide feedbacks to all stakeholders on what is going on in their respective localities regarding disposal and prevention activities in a coordinated manner.

1.3. **Working with media**

- Aired through Radio;
- Working sessions to reflect on issues of obsolete pesticides;
- Organizing panel discussions on use /misuse import and production;
- Preparation of scripts;
- Newsletter;
- Organizing developmental theatres / dramas/ songs; and
- Working with specialized NGOs (women, youth, advocacy group, etc).

**2. Monitoring and evaluation of disposal and prevention activities**

**3. Reporting and follow up of activities to concerned stakeholders**

**4. Conducting case studies in collaboration with Research Institutions**

- Identification of traditional pest control methods;
- Testing and identifying those qualifying as "good practices"; and
- Identifying current trends and practices of pesticide use, etc.

**5. Prevention**

- Assist in developing and implementing preventive measures;
- Assist the Government in the preparation and formulating, policies, legislations and enforcement measures;
- Actively participate in ensuring the development of viable alternatives to pesticides;

- Provide training to store-keepers and pesticides users on safe handling and uses; and
- Ensuring prevention of further accumulation of unwanted and obsolete pesticides.

6. **Farmers' empowerment**
   Assisting or leading to empowering farmers (men and women) so that they can make their own informed choices, ways and means they can use to control pests without pressure. If NGOs develop farmer's capacity to make their own enlightened decisions, future occurrence of obsolete pesticides problems can be tackled.

7. **Networking**
   Strengthening the existing networks through establishing resource centres and communication mechanism for the exchange of information and experiences among stakeholders, both nationally and internationally.

8. **Lobbying Government officials for ratification of different conventions**

9. **Organizing workshops and symposiums**
   - Regional workshop on: chemical conventions (Stockholm, Rotterdam (PIC), and Basel conventions);
   - Debates on technology choices; and
   - Capacity building (training) on report mechanisms, integration of economics to day-to-day activities, experience-sharing and cross visits (including farmers), safe handling of pesticides and implementing IPM and preparation of information materials.

10. **Fund raising for co-financing obsolete pesticides disposal (or risk reducing) efforts**

11. **Ensure safe use and disposal of pesticides containers in collaboration with all stakeholders**

12. **Identify uses of banned and restricted products** under the Stockholm and other chemical conventions particularly the use of *DDT* and other POPs.

13. **Participate in providing information** during inventory of banned or obsolete products in the national implementation of the Stockholm Convention and of obsolete pesticides disposal projects.

# Conclusion

Considering the seriousness of their impact on human health and on global environment, the issues related to the accumulation of pesticides and the specific treatment required by obsolete pesticide stocks are of great importance and priority to Ethiopia.

The disposal operations being very technical and costly are not viable and can not be implemented without the support from various organizations, both in terms of financial and technical backstopping. The implementation of various mechanisms aimed at avoiding the accumulation of pesticide stocks is essential. Those mechanisms are modulated according to the major causes of accumulation. In this respect, the actions are multiple, need to happen concomitantly and concern a large number of actors.

Initial steps have been taken now with the onset of the second phase of the Prevention and Disposal of Obsolete Pesticide Stocks project. Reviews took place making the initial analysis of the causes of the accumulation in the Ethiopian context. Proposals of remediation are on the table. Efforts are still needed in terms of allocating additional means and human resources to the various components of the prevention activities and to the reinforcement of partnership among various stakeholders.

In fact, if Ethiopia has to tackle the issue of obsolete pesticides globally, then all the society needs to be involved.

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