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PROCEEDINGS of the Third Annual Conference of the Crop Protection Society of Ethiopia

18–19 May 1995
Addis Ababa, Ethiopia

CROP PROTECTION SOCIETY OF ETHIOPIA

Proceedings of the Third Annual Conference of the Crop Protection Society of Ethiopia

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CROP PROTECTION SOCIETY OF ETHIOPIA

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CONTENTS

The Crop Protection Society of Ethiopia

The Crop Protection Society of Ethiopia (CPSE) 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 CPSE is to contribute towards the development of Ethiopian agriculture by reducing crop losses caused by plant pathogens, insect and vertebrate pests, and weeds through research and dissemination of research results; and by fostering a united approach among professionals and disciplines.

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List of Abbreviations

ACA	Awasa College of Agriculture
ADCPD	Agricultural Development and Crop Protection Department
AUA	Alemaya University of Agriculture
DLCO/EA	Desert Locust Control Organization for Eastern Africa
DZARC	Debre Zeit Agriculture Research Center
EASC	Ethiopian Agricultural Sciences Congress
ESTC	Ethiopian Science and Technology Commission
IAR	Institute of Agricultural Research
ICARDA	International Center for Agricultural Research in the Dry Areas
ILRI	International Livestock Research Institute
JCA	Jima College of Agriculture
MOA	Ministry of Agriculture
MSFCTD	Ministry of State Farms Coffee and Tea Development
PHC	Plant Health Clinic
PPRC	Plant Protection Research Center

OPENING SESSION

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Welcome Address

Dereje Ashagari
President, Crop Protection Society of Ethiopia
MOA/ADCPD, P.O. Box 62347, Addis Ababa

Your Excellency, Ato Sintayehu G/Mariam,
Vice Minister of Agriculture;
Invited Guests;
Members of the Crop Protection Society of Ethiopia;

It is a great pleasure and honor for me to welcome you all to the Third Annual Conference of the Crop Protection Society of Ethiopia. It is also a great honor and privilege for me to extend on behalf of the executive committee and myself our appreciation to Ato Sintayehu Gebre Mariam for his presence among us for opening this third annual conference of the Crop Protection Society of Ethiopia. We are also pleased to have many distinguished guests attending this session of the conference. Their presence is an encouragement and support to our cause and we thank them for this.

Ladies and Gentlemen,

The Crop Protection Society of Ethiopia is formed as it is clearly stated in the objectives of its constitution, to: (1) foster a more united approach among professionals to solve crop protection problems and to serve Ethiopia's agriculture in a more efficient manner, and (2) contribute towards national crop protection development policies by recommending areas of research priorities, manpower development, and ways of coordinating on the utilization of the existing national resources. The sole aim for this is, of course, to enhance the productivity of the agricultural sector for the eventual realization of self-sufficiency in food, clothing and shelter.

The crop protection Society of Ethiopia since its establishment in 1992 through the merger of the two previously formed committees (Ethiopian Phytopathological Committee and Committee of Ethiopian Entomologists) has been now able to hold three annual conferences successfully. In each of these conferences research papers in surveys, loss assessments, biological studies, cultural practices, chemical control, physiology, epidemiology, host resistances have been and being presented and discussed in the entomology and pathology sessions. In addition topics of general interest and/or special importance such as the role of crop protection in the national agricultural development, locust pests in Ethiopia, quelea control operations in Ethiopia, integrated pest management, etc. have been raised and discussed in the plenary sessions. All of these, of course, have been very useful in the exchange of ideas among researchers, in providing useful information to user communities, creating awareness to the importance of crop protection etc.

Ladies and Gentlemen,

As you may have noticed in the program, a total of 34 papers, i.e., 4 in the plenary, 17 in entomology, 13 in plant pathology sessions will be presented today and tomorrow. In addition there will be a business session towards the end of the second day.

This conference is sponsored by the Institute of Agricultural Research, Ethiopian Science and Technology Commission, Ciba - Geigy Co., Al-Mesh Pvt. Ltd., Makobu Pvt. Ltd. Enterprise, Chemtex Pvt. Ltd. Enterprise, BASF, Filbert Co., and RHONE POULENC.

The Crop Science Society of Ethiopia has provided some material support in the publication of our proceedings. On behalf of CPSE, I would like to express our sincere appreciation and gratitude for their support.

With this, I now respectfully invite Ato Sintayehu G/Mariam, Vice Minister of Agriculture, to open the third annual conference of CPSE.

Thank you.

Opening Statement

His Excellency, Ato Sintayehu Gebre Mariam,
Vice Minister of Agriculture

Mr. Chairman,
Members of the Crop Protection Society of Ethiopia,
Invited Guests,
Ladies and Gentlemen

It is a great pleasure for me to address the Third Annual Conference of the Crop Protection Society of Ethiopia which is being held at a time when we have rowed to substantially increase our agricultural production through: (1) the adoption and implementation of participatory demonstration and training extension system, (2) better supply and availability of improved technologies and required inputs, and (3) better credit facilities.

A large number of food and cash crops are grown in Ethiopia. The average yield of these field crops is about 11 quintals per hectare. Such yield is appallingly low compared with potential yields obtained at research centers and extension sites. A combination of factors related to problems of technologies, weather, pests, etc. could be cited as causes for the low yields.

In Ethiopia pre- and post-harvest losses due to various pests and diseases are believed to reach 30-40%. Several measures including cultural, biological, and chemical methods could be considered for the control of the injurious crop pests and diseases.

Ladies and Gentlemen,

The bulk of pest/disease control recommendations in the past relied heavily on the use of pesticides. However, the high cost of pesticides, their unavailability, the resurgence of pests, the level of know-how by the small farmers, in addition to the environmental hazards and danger to human safety make the reliance on pesticides questionable. Although reliable and comprehensive data are lacking, incidence of livestock and human poisoning have been reported due to improper use and, lack of control, of pesticides. These indicate the need for an alternative approach to pest control.

Nowadays, the pest management strategy considered has to be sustainable, environmentally friendly, economically sound, and socially acceptable. Such pest management strategy is known as "integrated pest management" (IPM). While the basis for IPM is adequate knowledge of the ecology and dynamics of the pest and its natural enemy population, its components include the skillful blending and wise use of the available control measures.

Integrated pest management is being adopted as pest management policy in quite a number of countries; developed and developing. This approach has helped these countries to considerably reduce their dependency on pesticides. In the USA the implementation of large scale IPM programs has cut down the use of pesticides by more than 50 percent on such crops as cotton, tobacco, sorghum, peanuts, oranges and grapes. Similar IPM approach has also resulted in a drastic reduction in the use of insecticides on cotton in Central America. In many South East Asian countries IPM has also received a considerable attention. In Ethiopia some preliminary studies on the ecology and population dynamics of bollworms on cotton, scale insects on citrus, stalk borers on maize and sorghum, and stem maggots on haricot bean have been carried out. Results from some of these studies have been implemented. For example, calendar insecticide applications that were previously practiced in cotton and citrus have been replaced by spray applications carried out only when needed; reducing pesticide consumption. As the emphasis of IPM is on optimization of control rather than eradication of the pest, it is equally applicable to small as well as to commercial farming. The Ethiopian farmer essentially practices an IPM when he grows small patches of mixtures of several crop species in one field. This creates heterogeneity and diversity which impose a physical barrier to the spread of the pest and/or encourages the multiplication of useful parasites and predators of the pest. What is now required from researchers is establishing scientific basis to what the farmer already knows and devising technologies that can help improve upon existing knowledge.

Mr. Chairman,
Ladies and Gentlemen,

I understand that the development of integrated pest management systems to all important pests require resources, highly trained manpower and time. I also understand that some efforts are being made by our research institutions and extension establishments in the development of IPM. I believe more is needed to be done in this area. I am glad to know that the Crop Protection Society of Ethiopia has selected IPM as the theme of this conference in order to create awareness among its members. Indeed this is a big contribution in promoting the crop protection program of our country. The development and promotion of IPM is a challenge to all members of your Society, particularly to entomologists and pathologists engaged in research and extension. They need to focus on the establishment of baseline data and development of sustainable and environmentally sound pest management practices. The Ministry of Agriculture in its part would give every support in the efforts to enhance the development and promotion of IPM.

Finally, on your behalf and myself, I would like to thank all those who have been involved in organizing this annual conference.

With this remark, I declare this conference officially open and wish you every success in your deliberations.

Thank you.

Key-Note Address

Mengistu Hulluka
Academic Vice President
Alemaya University of Agriculture
P.O. Box 138, Dire Dawa, Ethiopia

Mr. Chairman,
Honorable Participants,
Invited Guests,

It is indeed an honor and privilege for me being given this opportunity to deliver a key note address to this body assembled in this grand occasion to participate in the Third Annual Conference of the Crop Protection Society of Ethiopia.

There is nothing more gratifying than to see such a large force of younger faces of professionals in the field of crop protection engaged in fostering research and development in order to alleviate the principal crop production constraints. It is indeed your drive and attitude towards professionalism which brought you together to this annual event in order to promote a more united approach to confront the challenges in crop production.

Increasing number of our young scientists are now making the profession as their career not only that there is a better opportunity in this specialization but also in being aware of the vastness, complexity and diversity of the problems. A force greater than currently attained and in more diversified specialization is demanded to alleviate not only the current problems, but also to protect our crops from the incoming man-introduced natural enemies.

However, engagement in research by such a large body of forces by itself is a partial victory, I must say, over the enemies of crops, though our farmers are still being challenged daily by resurgence of calamities due to pests, diseases, weeds, rats and birds, to name a few.

Our struggle in the past, as a team, has made substantial headway in developing pest control measures, in the legislation of some aspects of cop protection activities, such as drafting a policy governing the quarantine system and on the use of pesticides. Inspite of such achievements we don't need to be-reminded how much remained to be attained in our goal of reducing the ever increasing danger of crop pests.

The incoming danger can be averted only if we cohesively confront the challenges by intensifying our research engagement. In his recently released book, entitled "Feeding and Greening the World: The role of International Agricultural Research", Derek Tribe concludes that increasing agricultural productivity through agricultural research offers the only possible means for confronting the effects of expected population growth on the world food situation 20 years from now. Tribe argues that many of the world's problems could be solved with better application of scientific knowledge, resulting in substantial benefits to both developed and developing countries: benefits to the economy, the environment, and most important, to the people of the world.

Tribe says, " Greater investment in cost-effective agricultural research is essential if we are to solve problem of world overpopulation, poverty, hunger, and environmental degradation".

"Although there is enough food in the world today to feed everyone, available food is neither evenly distributed nor fully consumed. More than 700 million people now suffer from lack of food. Diseases of hunger and malnutrition are widespread. And the environment is suffering from the efforts of poor people to satisfy food needs, even at the cost of future food production".

"One-third of the total population of the developing world is poor, and 18% is at the point of starving, according to World Bank Data. Poor women are universally worse-off than poor men. Just as improving the lot of the poor reduces the birth rate, improving farming methods results not only in increased agricultural production, but also in more jobs, both on-farm and in rural villages, as higher incomes lead to increased demand for goods and services. In many countries, between two - thirds and three - quarters of new jobs have resulted from improvements in agriculture".

"In Indonesia for example, in 1970 - 87, rapid technological change in agriculture was accompanied by a surge in rural employment, and poverty declined by 41 percent".

Despite the unprecedented gains engendered by agricultural research in the past 40 years, food production in most countries is well below its potential. Research could still improve yields sufficiently to feed future populations. But without adequate support of the institutions and individuals who perform research leading to technological breakthrough, the potential may never be fulfilled.

Agricultural research is vital because it is the source of new production technology, and new production technology is the source of economic growth, according to G. Edward Schuh, the former director of the Agriculture and Rural Development Department of the World Bank.

"New technologies must also be sustainable and protecting natural resources. Without adequate funding directed to agricultural research, ways to combine the demands of increased productivity with environmentally sound solutions may not be found".

The role of crop protection research in the grand national agricultural research scheme in improving production is much higher and substantial. Sustainable agricultural development cannot be attained without sustainable crop protection programs. In intensifying our agricultural production systems for increasing yield and quality of crops it calls for a larger share of our involvement.

For Africa to meet its future needs and avert serious environmental problems, a far greater proportion of its food production gains must come from intensification and yield improvement, and a smaller proportion from expanding the cropping areas. Estimates by FAO, for example, suggest that "by the year 2000 about one - half of the necessary food production gains should come from yield increases, about one-quarter from increased cropping intensity, and about one-quarter from expanding the amount of arable land."

The formidable task in this intensification processes is the selection of the best and practical methods or approaches to avert pest damage and preparedness to meet the challenges. As if it is our only way out, most specialists in crop protection adopted a "total system" approach to pesticide management that covers all areas of pest control. Such perception has been rejected by developed and environmentally conscious nations and are gearing themselves in the development of means which are biologically safe and environmentally sound approaches. The whole effort is to reduce the number of pesticide applications.

One such area where quite a number of researchers currently engaged in reducing pesticide use is what is referred to as Integrated Pest Management (IPM) strategies. Under some conditions this system has passed the development stage and is in the process of being implemented for farmers use, even in highly developed countries. Some commercial farmers have begun realizing the usefulness of IPM programs, as it provides the tools by which they can increase revenues and lower risk while reducing pesticide use.

IPM strategies include risk assessment, forecasting and monitoring, use of resistant cultivars, use of bio - insecticides, disruption of insect mating, release of natural enemies, and judicious use of pesticides. In this regard IPM specialists and IPM practitioners continue to refine the program to bring about maximum benefits.

I think IPM strategies is the best hope for most of our small-scale farmers, as it is like reverting back to their old practices which they have been utilizing for centuries. Valuable indigenous knowledge regarding pest management is being undermined in research areas in this country in spite of its usefulness for centuries. To name some examples, the use of landraces for most crops has averted disaster in the past. Currently, some European countries appreciated diverse genetic background in crops and resorted back to producing crops with mixed varieties to reduce risk in case of change in pest strains. Some traditional cultural practices must also be revaluated and studied further. Others have taken advantage of and have benefitted from some of our natural resources which we preserved for centuries but failed to develop them to our favor. For example, the pesticidal value of some of our indigenous plant materials have not been given their due share of attention.

Maybe some of us have to look into the potential in our herbs as pest control strategy, specially in an era when the vast array of tools are being developed to transfer characters, genes, from one organism to the other, irrespective of their relationship. The science of biotechnology and genetic engineering is currently considered to be the future strategy to defeat most of the pest problems. Unfortunately none of us, it seems, is engaged in either acquiring the science or in the practice of using it as our future tool to ward-off the forthcoming pest problems.

I think we must be in line with the current thinking and development in science and may have to modify our laboratories to accommodate this approach for effective pest control, as this technology may offer the necessary tool to face the challenges of the future.

In facing the challenges of the future, another area where very little attention has been given and slow advancement being made is the post-harvest problems in this country. Voluminous quantity of our farm produces are still not being consumed due to post - harvest problem. Had we taken effort to reduce the amount lost through poor harvesting and handling, poor transportation and backward marketing methods, both at wholesale and retail levels, we could have saved millions of quintals of our farm produces. The envisaged increase in agricultural output which some of our policy makers are talking about can be attained only by conserving our crops from being destroyed by rats, weevils, molds, and the like. According to current estimate, 30% of harvests in developing countries are being lost due to post-harvest problems, whereas, in developed countries they have reduced the loss in an area between 5-10% yearly. In my view this has been a rich researchable area to reduce losses in storage, packaging, and transportation systems.

I think it is about time to devise ways on how to make use of all products of our farmers for the well-being of the masses while we indulge ourselves in expanding the area of crop production and intensifying our effort with high input agriculture.

Mr. Chairman,
Ladies and Gentlemen,

Our past effort through discussion in such conferences and meetings have brought about some progresses in agricultural development. It has been through expert constructive advice and repeated call of attention we were able to make some progresses. The formulation and establishment of the National Agricultural Council is a step in the right direction. More than ever, there is a positive sign and an intention to make some headway in agricultural development by promoting research. Along with this gesture, our organizational capability must be strengthened, more funding must be allotted for targeted research, and more encouragement must be given to our researchers to score breakthroughs in solving agricultural problems and attain sustainable production.

Our researchers must, on the other hand, start assessing the tangible values of their research in terms of economic benefits to the society at large. In order to win substantial amounts of grants the rate of return for such huge investment on research projects need to be quantified and we should be accountable to the benefits generated. To cite an example, " the rate of return for one rice research project at CIAT, in Colombia was calculated at 69 percent, and the expected benefits between 1990 and 2010 were calculated to be worth more than 2 billion dollars: (Tribe, 1994).

Concerted effort by all concerned is a must inorder to bring about such a change in agricultural development. As a Society of Crop Protection more is expected of us in our professional area to tackle the pest problems. With positive outlook no challenge is insurmountable.

Thank you.

PLENARY SESSION

Integrated Pest Management: Concepts and Principles

Abdurahman Abdulahi
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Abstract

The development of synthetic organic pesticides has led farmers to rely much less on other pest control measures. This in turn gave rise to various problems. Some of these are direct hazard to the users, resistance development, secondary pest outbreak, pest resurgence, residues in food and environmental contamination. Recognition of the problems associated with pesticide use has led to the development of integrated pest management (IPM).

IPM is an ecologically based pest control strategy that utilizes all suitable pest control methods in as compatible a manner as possible and maintains pest populations at levels below those causing economic injury. Its major principles are understanding the agro-ecosystem, utilization of economic threshold and avoidance of disruptive actions. The main components of IMP include biological control, mechanical/physical control, cultural control, host plant resistance and chemical control. Pesticides are used as a last resort when the other methods have failed to provide the desired degree of control. During such time the safest pesticide, formulation, time and method of application are used.

Introduction

The history of agricultural pest control is as old as agriculture itself. Long before 2500 B.C. sulfur compounds were used by the Sumerians for the control of insect pests and mites. The use of fire for locust control was recognized long before 950 B.C. Around 300 A.D the Chinese found out the use of predatory ants for the control of caterpillars and large boring beetles in citrus orchards. From 1870-1890 Bordeaux mixture and Paris Green were used for the control of plant diseases. The use of resistant varieties of crops for disease control was first recognized between 1899-1909. However, the major break through in pest control came in the 1940s when synthetic organic pesticides such as DDT, Lindane (HCH), Aldrin and Dieldrin were developed (Flint and Van Den Bosch, 1983). After that pest management became increasingly dependent upon pesticides and farmers come to rely much less on other pest control measures such as tillage, crop rotation, and natural enemies of pests.

Unfortunately not long before the use of pesticides became widespread, several types of problems associated with pesticide usage started emerging. The major ones are direct hazard to the users, resistance development, secondary pest outbreak, pest resurgence, residues in food and environmental contamination (USAID, 1991). Direct pesticide hazard to the user is particularly serious in the developing countries where only 20% of pesticides are used, but account for 50% of all pesticide poisoning and 73-90% of all pesticide related deaths (USAID, 1991). Some of the health related problems caused by pesticides include cancers, birth defects, reduced fertility, nervous disorders, paralysis, blindness and skin disorders. Latest evidence also suggest that excessive exposure of the developing male embryo to "oestrogen mimics" such as organochlorine pesticides led to the development of homosexuality (Tuarmora). Pesticide resistance is another major problem associated with pesticide usage. In 1984, 638 pest species were reported to have developed resistance to one or more types of pesticides. Of these, 428 are arthropod pests, 50 are weeds, 150 are plant pathogens and 10 are small mammals and plant parasitic nematodes (USAID, 1991).

Concepts of IPM

Recognition of the problems associated with widespread application of pesticides have necessitated the search and development of alternative pest control strategies. The approach that has been found to overcome the problems associated with pesticide usage and provide an effective pest control is the Integrated Pest management (IPM). This approach is also sometimes known as Integrated Pest Control (IPC) in European countries.

IPM is defined as a pest management system that utilizes all suitable techniques and methods in as compatible a manner as possible and maintains pest populations at levels below those causing economic injury (USAID, 1991).

As it is stated in the above definition IPM relies on the use of all available pest control methods in as compatible a manner as possible and with minimal disruption to the ecosystem. From this it can be concluded that IPM is area specific and needs to be developed for specific crop/pest complexes in particular locations. IPM technologies that have been developed in one country cannot be imported into another country where natural enemy situations, environmental conditions and economic factors are different.

Principles of IPM

IPM is based on sound scientific principles. The major ones include consideration of the ecosystem, utilization of indigenous natural control agents, maintenance of the ecosystem complexity, avoidance of disruptive actions, application of minimum selective hazards, exclusion from new areas, crop adaptability to ecosystems and utilization of economic thresholds (National Academy of Sciences, 1969).

Consideration of the Ecosystem. The first principle of pest control is consideration of the ecosystem. An ecosystem is defined as an area that includes living organisms and non-living substances and the interactions that occur between them. The development of sound pest control strategy requires understanding the principles underlying for the fluctuation of populations that make up the ecosystem.

Utilization of Indigenous Natural Enemies. The population density of pests are usually kept under low level by their natural enemies. Agricultural pests reach pest status often as a result of man's activities. It is important, therefore, to take maximum advantage of natural enemies for control of agricultural pests.

Maintenance of the Ecosystem Complexity. The population density of pests generally fluctuate significantly under monoculture conditions, and are more stable under polyculture conditions. From the stand point of pest control, it would be desirable to practice polycultures rather than monocultures.

Avoidance of Disruptive Actions. Pest populations usually reach injurious levels as a result of man's activities. Hence, it is important that disruptive actions need to be identified and either avoided or minimized. The use of host plant resistance and natural enemies are considered least disruptive to the ecosystem. When the use of pesticides becomes necessary, the selection of safest ones, formulation, dosage, application method and time is necessary.

Application of Minimum Selective Hazards. The application of pesticides to pest populations in such a manner that target populations are kept below economic injury levels is necessary. Such measures would help to avoid or delay the development of resistance, decrease the possibility of pest resurgence, reduce adverse effects on non-target organisms and the degree of environmental contamination and lower the cost of control.

Exclusion from New Areas. Most pest species occupy only small portion of the area that is suitable to them. If they get an opportunity to enter into a new area they could cause more damage than in their original area where their population density is generally maintained at low levels by their natural enemies. This shows that much effort is needed to prevent the introduction of pests into new areas.

Crop Adaptability to Ecosystem. Some pest species are widely spread in certain areas than in others. Therefore, it is just as important to conduct pest surveys as it is to conduct soil surveys and study the climate of an area before deciding whether to grow a crop or not. Realistic pest management strategy requires that certain crops should not be grown in areas where there are serious pests that would attack the crop.

Utilization of Economic Threshold. Economic threshold is the basis of pest-management. It may be defined as the density at which pest control measures are taken. This definition clearly states that pest control measures should be taken when the loss caused by a pest just equals in value to the cost of control measures. Any pest control measures undertaken without considering economic threshold is unjustified.

Components of IPM

The components of IPM has been discussed by Flint and Van den Bosch (1983), Metcalf and Luckmann (1975), Kumar (1986), USAID (1994) and many others. The major components are briefly discussed as follows:-

Biological Control. Biological control is one of the major components of IPM. It may be defined as the deliberate use of natural enemies, namely parasites, predators and pathogens. It is cheap, effective and non-disruptive of other elements of the eco-system. Unfortunately, it is the factor most likely to be disturbed by other methods. The three main approaches of biocontrol are classical, augmentation and conservation. The classical biocontrol is the introduction and establishment of natural enemies in areas where they did not exist previously; augmentation biocontrol is mass production and release of natural enemies to control pests, and conservation biocontrol refers to enhancing the environment so that it is more favorable for natural enemies.

Host Plant Resistance. Host plant resistance involves the manipulation of the genetic make up of the host plant so that it is resistant to pest attack. It is an ideal method for use in integrated pest management programs. Once a resistant plant is developed, the cost of using this method is minimal to the farmer. Moreover, use of host plant resistance is environmentally sound and can be readily integrated with other methods of pest control.

Cultural Control. Cultural control refers to the modification of management practices that are used to make the environment less favorable to pest reproduction, dispersal, and/or survival. They include some of the oldest pest control practices known. Since cultural controls are usually modifications of operations that would have been carried out in any case, the cost of their incorporation into pest management practices are minimal.

Mechanical and Physical Control. Mechanical and physical control are measures that are taken to destroy pests or make the environment less favorable for their entry, dispersal, survival or reproduction. These methods differ from cultural control as they are taken specifically to control pests and are not merely modifications of management practices. The use of these methods in agriculture is often limited because of the high labor requirements. Despite this, traditional pest control practices often use these methods and need to be integrated into IPM program where appropriate.

Chemical Control. Chemical control is the method currently available for the control of certain pests. This trend will undoubtedly continue in the coming decade. Pesticides should be used as a last resort when other methods of pest control failed to provide the desired degree of control. When the use of pesticides becomes necessary the safest pesticide, formulation, dosage and method of application should be selected.

Genetic Engineering. This is a new technology that is adopted for pest control purposes. Examples of genetic engineering include plants that are genetically engineered to produce pesticides that normally are produced only by bacteria. Although it is not widely used currently in the developing countries, it may be one of the most important components of IPM in the near future.

Conclusions

Currently, there is no better strategy than integrated pest management for the management of agricultural pests. Integrated pest management is economically feasible, environmentally sound and socially acceptable method. As a result, it is widely used in the develoepd and some developing countries. On the contrary, not much progress has been made in the development and implementation of IPM in many developing countries. As there is no better strategy than IPM, developing countries need to give due consideration for the development and implementation of IPM. Since IPM cannot be imported from other countries it has to be developed in the country. This requires the allocation of necessary resources both in terms of manpower and development costs.

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Integrated Pest Management in Ethiopia: An Overview

Tesfahun Fenta
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Abstract

Crop pest management has been a task of the peasant sector and mostly relied on an age-old cultural practices. Integrated Pest Management (IPM) is a key component of sustainable agriculture. The advantage of IPM for farmers in developing countries has been clear for many years though its implementation is relatively limited. It cuts production costs by reducing reliance on expensive agrochemicals, reduces hazards to both humans and the environment and at the same time stabilizes yields by ensuring the survival of natural enemies to major pests.

In view of this the paper discusses current status of its IMP research and implementation in Ethiopia. The major constraints in the use of IPM includes insufficient emphasis to IPM, lack of trained personnel lack of know how and resources to implement IPM technology and inadequate recommendations on locally available and sustainable resources.

Introduction

One of the crucial problems in Ethiopia today is the acute food shortage that confronts a rapidly increasing population. Among the major contributing factors to this situation are poor crop yields and high losses at pre and post harvest attributable to crop pests. Although the magnitude of losses from pests has not been accurately or adequately measured even in the most highly developed countries, such losses are recognized being substantial. An estimated 50 percent of the food produced in Africa is lost each year to pests and weeds (Topic, 1993). Though crop loss estimates for Ethiopia is not available, it is expected not to be less than the average figure indicated above.

During the 1950s, agricultural production grew rapidly when new high-yielding crop varieties were introduced and new chemicals were used with increasing success to control insect pests, diseases and weeds. It was optimistically predicted that an adequate food supply could soon be provided for the fast growing world population (Zelazny et al 1995). However, new pest problems appeared quickly. Insects developed resistance to pesticides and previously unnoticed arthropods became important pests. Likewise, plant pathogens rapidly adapted to new chemical and disease breakdowns occurred in previously resistant varieties. This resulted in serious outbreaks and epidemics. It became clear then that the problems were caused by the disturbance of the delicate ecological balance of the traditional cropping system.

Obviously a new approach in crop protection was required. The concept of, integrated pest management (IPM) was developed in the late 1950s from these considerations. The original definition envisaged "applied pest control which integrate biological and chemical control is used in a manner which is least disruptive to biological control". Many scientists regard such a definition as too restrictive and would view chemical control as a last resource when other methods fail to keep a pest in check. More recently, the concept of IPM has been applied to the integrated control of different types of pests (for example, insect, disease and weeds) in the same crop. Although originally distinct, the two terms integrate pest control and IPM, are now used almost interchangeably to imply both concepts.

IPM (Integrated pest management), a strategy based on biological control, host plant resistance and habitant management, is making its mark as a viable, ecologically sound and cost effective way to keep pests from devouring a farmers crop and livelihood. IPM application is based on considerable understanding of the biology of pests involved and their natural enemies. The advantage of integrated pest management for farmers in developing countries have been clear for many years. It cuts production costs by reducing reliance on expensive chemicals, reduces hazards to humans and the environment and at the same time, stabilizes yield by ensuring the survival of natural enemies of major pests (Loo G.W. 1990). This paper is reviewing the currently prevailing state of the art of IPM in the country with the aim of improving the existing practices and making the research approach more relevant and systematic taking into consideration the available scare resources of the country.

State of Crop Protection Research

Crop protection research in Ethiopia is a relatively recent field of agricultural research. Some years back there had been little work on crop protection research except for a general survey work on pests and diseases. These surveys have given basis for many current research undertakings. Since then, specially after the establishment of institutions engaged in crop protection research, much progress has been recorded in applied and supportive research works. Inspite of the research endeavor, the need for crop protection research is still enormous (Tesfahun F., 1992).

In reviewing the research undertakings over the years, initially the emphasis had been on surveys, and later more attention was given to effective control measures, mostly by adopting technologies already in use in other countries, the emphasis being on testing the adoptabilities of technologies under our condition (Mengistu H. 1989).

Over three years (1992 - 1994) about 345 research activities are being carried out in various institutions engaged in crop protection research (Table 1). Most of the endeavor fall within three categories, namely pest surveys, varietal screening for resistance, and chemical or pesticide screening. Altogether this constitutes about 70% of the operation, the remaining activities encompass researchs on cultural control methods, variability studies, loss assessment studies, epidemiology and population dynamics. Very minimal studies were undertaken on etiology, biological control and integrated pest management. (Table 1).

Table 1. Summary of Crop Protection Research Activities by types of research (1992-1994)

Type of Research Activities	IAR*	AUA	ACA	MOA (CPRD)	TOTAL
Applied Research	143	34	4	13	194
Chemical control	32	12	-	6	50
Cultural control	23	5	1	2	31
Biological control	10(6)*	-	1	3	14
Host plant resistance	71	12	1	-	84
Integrated pest management (IPM)	7	5	1	2	15
Supportive Research	111	22	4	14	151
Survey & identification	54	7	1	7	69
Biology	7	1	1	2	11
Population dynamics	6	1	-	2	9
Variability study	11	3	1	-	15
Host range	6	-	-	-	15
Loss assessment	13	2	-	2	17
Epidemiology	8	7	1	1	17
Etiology	4	1	-	-	5
Methodology	2	-	-	-	2
TOTAL	254	56	8	27	345

Source: (AUA 1991/92, 92/93, 93/94, and IAR 1991/92, 92/93, 93/94)

*IAR, Institute of Agricultural Research; AUA, Alemaya University of Agriculture; ACA, Awassa College of Agriculture; MOA, Ministry of Agriculture; CPRD, Crop Protection and Regulatory Department; MOA, Ministry of Agriculture

** Figure in the parenthesis indicate number of research activities dealing with botanicals

In terms of application of research findings, the use of pesticides and resistant varieties becomes prominent for obvious reasons (Mengistu H. 1989). The trend to favor the use of chemicals is more often than the other control measures. The success of using chemicals has over shadowed works on other spheres of pest management. Thus integrated pest management needs to get more attention if it is to be strengthened.

Current Status of IPM

IPM has long been recognized as an important approach dealing with insect pest and disease control even though IPM projects are heavily skewed toward entomology (Zadocks J.C. 1989). In recent years, attempts are being made by research institutions to integrate pest control tactics in Ethiopia.

Research Aspect

IPM is based, among other things on the complete understanding of the population dynamics of pests so that appropriate control strategies can be developed. Studies on IPM have been carried out for some of the major pests in Ethiopia. Examples include studies on the ecology and population dynamics of bollworms on cotton, scale insects on citrus, stalk borers on maize and sorghum and stem maggots on haricot beans. In reviewing the research undertakings over the past three years (1992-1994), the number of IPM research activities is relatively very small compared to others like chemical control, survey and identification (Table 1). Substantial amount of research work is being carried out in host plant resistance. This component is easy to adopt by the farmers. Host plant resistance is generally compatible with other IPM components and requires minimum financial input from the farmers, except for high-yielding varieties which may need high level management.

Research trends that have already started in the study of alternative approaches such as cultural, biological and development of resistant/tolerant cultivars of varieties are continuing to improve from time to time, though the trend to integrate the components and test for compatibility and efficacy under various ecological conditions is not satisfactory. The number of research activities which can serve as a component of IPM is very big as compared to very few IPM research activities as indicated in Table 1.

In recent years research in the use of botanicals is relatively being widely undertaken in Ethiopia. For example experiments conducted at Awassa College of Agriculture, various centers of IAR, crop protection laboratory of MOA and Jimma College of Agriculture revealed that products of neem (*Azadirachta indica*) and other plant species, including pepper tree (*Schinus molla*) and persian lilac (*Melia azadirachta*) give effective control of several species of stored product pests (UNDP, 1993). Research should be intensified to expand this work to include crop pests, and to extend the available results to the user community. Another area which serve as key component of IPM, is biological control, with special emphasis on the exploration, isolation and development of microbial pesticides from locally occurring organisms. Grasshopper pests, desert locust and caterpillars such as the armyworm and African bollworm are obvious candidates for this initiative.

IPM Practices

Although appreciable amount of knowledge on pest and disease management exists, the average Ethiopian farmer makes little use of the improved technologies. Perhaps the most widely researched aspect of pest management in Ethiopian has been the use of pesticides against major pests and diseases of major crops.

The major beneficiary of integrated pest management research results has been the state sector. For example calendar pesticide applications that were common practice against CBD in coffee, bollworms in cotton, scale insects in citrus and tobacco whitefly in cotton in the late 1970s and early 1980s have been replaced by spray applications carried out only when needed, thus resulting in substantial reduction in pesticide consumption (Tsedeke A. 1985).

The emphasis in IPM is on optimization of control tactics rather than attempting to wipe out the pest. In this respect, IPM is equally applicable to subsistence farming as it is to commercial agriculture. In fact, IPM should not be regarded as a new technology to the small scale Ethiopian farmer who is already practitioner in IPM. It is not uncommon for the Ethiopian farmers to grow small patches of mixtures of several crop species in one field. His field is not usually clean; weeds will always be present as either in the crop field or on the periphery. This creates heterogeneity and diversity, which may impose a physical or chemical restriction on a potential pest/disease. Perhaps, this may be an explanation for the rare occurrence of pest and disease outbreaks (save migratory pests such as the armyworm and desert locust) in subsistence agriculture. Thus what is required by researchers is giving a scientific basis to what the farmer already knows and devising technologies that can help improve upon existing knowledge.

Major Constraints

The crop protection research in general and integrate pest management in particular face problems in the research and implementation aspect. The most important of these constraints are summarized as follows.

Insufficient emphasis to IPM. Though some attempts are made in undertaking research in the area of IPM, it seems very little compared to other areas of crop protection research, as indicated earlier. It is therefore very imperative that pest management must enter another phase where emphasis should be given to sustainability. In this regard sufficient emphasis is not given to IPM.

Lack of trained manpower: The number of researchers in crop protection is not sufficient compared to the magnitude of the problem. Besides, most of the researchers are of limited experience. One can realize the crucial need of experienced protectionists in the country to undertake research in IPM and further plan the implementation aspect considering the diversity of pest complexes under existing ecological environments and cultural practices.

Lack of know how to implement IPM technology. Clearly, IPM requires that farmers have a better knowledge of both the pests and their natural enemies than is the case with simple chemical control. It is also difficult for farmers to "do nothing" until the pest reaches an economic threshold, even though it is clearly present in the crop. This is particularly true if, previously they have been advised to spray at the first signs of the presence of the pests. It is therefore very indispensable to train farmers directly in IPM technology in order to implement it effectively.

Lack of capital: Traditional farmers are generally resource-poor and depend largely on their small plots of land and family labor. They also often lack proper farming tools and draft animals, and cash to purchase seed and fertilizer. In effect, this situation calls for the development of "zero input" IPM technologies with respect to the farmer and needed supply of these basic inputs at affordable terms.

Inadequate recommendations on locally available and sustainable resources. Although considerable amount of knowledge on pest and disease management exists, the average Ethiopian farmer makes little use of the improved technologies. Perhaps the most widely researched aspect of pest management in Ethiopia has been the use of pesticides against major pests and diseases of major crops. Thus pesticides are not affordable by the majority of the farmers. Traditional farmers have for generations applied natural plant products with pesticidal activity for pest control which have advantages over synthetic pesticides. In view of this, farmers' traditional practices can be improved through research, once their potential as a viable technology-ascertained. This area of research is not given due attention, as a result there is no recommendation in this respect, even though recently use of botanicals (plant products) is gaining popularity among entomologists.

Integrated pest management is a key component of sustainable agriculture. It is based, among other things, on the complete understanding of the population dynamics of pests so that appropriate control strategies can be developed. Cultural, biological methods of control epidemiology and host plant resistance should be exploited where possible to minimize the use of chemical control.

IPM research in Ethiopia is not given sufficient emphasis. Research trends that have already started in the study of alternative approaches such as cultural, biological and selection or development of resistant/tolerant cultivars is continuing to improve from time to time so that better pest management strategy can be developed for each major insect pest. Furthermore, the attempt to integrate the components into an appropriate IPM technology and test for compatibility and efficacy under different ecological conditions should be strengthened. Obviously, classical biological control will not be a priority at the moment. Instead, strengthening research on host plant resistance and cultural practices can contribute to IPM programs in Ethiopia. Thus the components can be easily accepted and implemented as they are accessible for farmers. Classical biological control has to be strengthened too, though it is not a priority at the moment.

Significant emphasis has to be given to use natural crop protection i.e. use of natural alternative, botanical and plant products. This approach is very essential as the recommendation on locally available and sustainable resources is easily accessible for farmers. To implement the available IPM technologies popularization and training should be carried out through demonstration, on farm trials, etc.. for farmers.

It is clearly stated in the National Agricultural Research Policy and Strategy, which emanated from the National Science and Technology Policy that in order to reduce and control the polluting effects of agricultural chemicals on the environment (air, soil and water) research has to be undertaken on the proper and minimal utilization of pesticide in the country. This indicates that there is a need to devise appropriate IMP reseach proposals. As to the implementation aspect of IMP technologies, Ministry of Agriculture plays an important role using the national extension system. To implement the available

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IPM technologies popularization and training should be carried out through demonstration, on farm trials, etc.. for farmers.

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Rodent Control Demonstration in Tigray, Gondar and West Gojam

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Abstract

Rodent control on farm demonstration trials using an anticoagulant 0.005% bromadiolone was carried out at a total of 29 sits in Tigray, Gondar and West Gojam. In most cases considerable reduction (75-100%) rodent activity was obtained in the poison treated areas. As a result of anticoagulant treatments, 78.9 to 182.4 kg/ha of wheat and 169.3 kg/ha of barley were saved from rodent damage. The cost/benefit ratio of the treated areas ranges between 1:7.8 to 1:9.5 for wheat and 1:8.9 to 1:17.7 for barley crops. More importantly 1230, 788 and 252 farmers from Tigray, Gondar and West Gojam respectively were trained on the proper application of the anticoagulant rodenticide during the demonstration trials.

Introduction

Rodents are recognized as one of the major agricultural pests in Tigray and Gondar, mainly in the highland areas where cereal agriculture is important. *Arvicanthis* spp. and *Praomys natalensis* are the primary field rodent species damaging, wheat, teff, finger millet, sorghum and faba bean (Martin, 1994). The most frequently used rodenticide in Ethiopia is 4% zinc phosphide as farmers responded to the quick killing effect of the rodenticide. However, zinc phosphide (acute toxicant) bait causes bait shyness on animals ingesting sub lethal doses and leads to limited control success. Besides, it is broadly toxic and the risk to non-target animals is high. Anticoagulants are better than acute toxicants, because of efficacy and safety factor. However farmers do not accept anticoagulants it readily because of the delayed kill and they often claim the baits are ineffective.

Although various training programs have been conducted in the past the "know-how" of rodent control particularly the proper application of anticoagulants has not penetrated to the individual farmer (Jackson, 1986). In order to convince farmers of the value of an anticoagulant over zinc phosphide, a pilot rodent control demonstration project was initiated by the Food and Agricultural Organization beginning November 1993. The overall objective of the demonstration was to disseminate the appropriate rodent control particularly on the proper use of anticoagulant in reducing crop losses caused by rodents and help farmers achieve a greater degree of food security.

Materials and Methods

Training. Prior to the trial, 45 subject matter specialists and 78 development agents of Tigray and Gondar regions were trained on various aspects of rodent control methods inclusive of proper application of anticoagulant rodenticides. Subject matter specialists and development agents in turn trained the farmers through field rodent control demonstrations.

Field Rodent Control Demonstration. Twenty nine on-farm rodent control demonstration sites were set up in different woredas of Gondar and Tigray regions. The size of demonstration sites were in a range of 1.25 -5 hectares. The rodent control demonstration trials were divided into four phases: (1) pre-treatment census, (2) treatment, (3) post-treatment census and (4) monitoring and evaluation. One to three census techniques were used in each demonstration site during pre- and post-treatment census: (1) bait consumption (2) tracking tile activity (3) burrow activity. The treatment lasted for almost two months starting June 1994.

Bait Consumption. Hundred gram of whole wheat was placed in bait stations (section of bamboo tubes) for three days before and after treatment. Daily bait consumption was measured in spring balance and replenished to the original amount. Whenever there is a complete consumption of bait in bait stations, the bait material were replenished with double the quantity of the original bait.

Tracking Tile Activity. Tracking tiles (15-by-15 cm plastic floor tiles with one-half of the upper surface painted with duplicating ink) were placed on or near runways. Tracking tile activity was recorded daily for three days before and after treatment. Tiles were counted as positive when rat foot prints or dropping were present on them and negative if otherwise.

Burrow Activity. All burrows in the control area were plugged with vegetation in the area. The reopened burrows were counted after 24 hours. After completing the poison treatment and lag periods the burrows were plugged again and active burrows were counted after one day.

Poison Baiting. Bromadiolon (0.005%) poison baits were placed in a bait station (100 gram/station). Fifteen to twenty two bait stations were placed in each demonstration site. Bait stations were replenished by fresh poison baits every three days. The bait stations with complete or nearly complete "takes" of the bait material were replenished with about double the quantity the original amount. A lag phase of 3 days was followed pre treatment census and poison baiting to reduce pre-baiting effects. The lag phase followed poison baiting also allow the animal time to die rather than counted as unaffected.

Effectiveness of the treatment was measured by mortality estimates which was derived from pre and post-treatment census made in the treated sites (Spaulding an Jackson, 1983).

$$\%\ \text{mortality} = \frac{100\,(Pr-Po)}{Pr}$$

in which Pr and Po are the three days average of pre treatment and post-treatment census respectively. However for burrow census technique Pr and Po are the total number of active burrows during pre treatment and post treatment census respectively.

Monitoring and Evaluation. Rodent damage was assessed on the treated and untreated fields of wheat and barley at Wikro and Maichew. Yield from treated fields (Kg/ha) was determined and compared with untreated fields. Loss saved and a cost benefit ratio for the rodent control effort was calculated following the method of Ahmad et al., 1989. Cut tillers by rodents were counted along a diagonal in five evenly spaced 1m^2 quadrats before harvesting in a field treated with bromadiolone and in similar non-treated check fields. Four treated and one check field were used for each crop, wheat and barley. Yield was estimated by sampling 100 tillers from 5 quadrates in each treatment and reference fields. Hence damage was calculated as,

Number of tillers in 5 m^2 = T

Number of cut tillers in 5 = CT

Percent cut tillers $= \frac{CT}{T} \times 100$

Yield = Y gram/100 tillers

Number of cut tillers/ha $= \frac{CT}{5} \times 10{,}000$

Yield loss/ha $= \frac{Y \times CT \times 10{,}000}{5 \times 100 \times 1000}$ Kg/ha

Grain saved = Lr - Lt kg/ha

Where Lr = loss in reference fields

Lt = loss in treated fields

Results and Discussion

The mean reduction of rodent activity calculated from bait consumption and tracking tile activity in both areas were in the ranged of 77.2 - 100% (Table 1). This result was found to be acceptable, because a 70% or greater reduction in target population when at least two census techniques were used is considered satisfactory (Spaulding and Jackson, 1984). Although use of two or more census techniques may make the results reliable, the use of single census method should not be avoided (Ashton et al., 1984). Except in one case which is 68%, rodent activity calculated from burrow activity census method revealed 75-100% rodent population reduction. A total of 2270 farmers from Tigray, Gondar and West Gojam areas were trained on the proper application of anticoagulant rodenticide using the demonstrations. Average bait consumption at pre treatment, treatment and post treatment census were 1684, 2573 and 158.6 grams respectively in demonstration sites of Tigray

(Table 3). Similarly an average of 1490.5, 3142.7 and 165 grams of baits were consumed during pre treatment, treatment and post treatment periods respectively in the demonstration sites of Gondar area (Table 4). In general in all demonstration sites post treatment census bait consumption was much lower than the pre treatment census which could be attributed to the reduction of rodent population by the 0.005% bromadiolone treatment.

For monitoring and evaluation a cost/benefit analysis for the rodent control effort was carried out in Wikro and Michew to wheat and barley crops respectively (Table 5 and 6). In untreated wheat field rodent damage to wheat was 203.1 kg/ha (Table 5) equivalent to a loss of Birr 304.7/ha. Bromadiolone treatments resulted in reduction of rodent damage to wheat crop ranging from 78.9 - 182.39 kg/ha. Hence the cost/benefit ration ranged between 17.82 to 1: 9.52. The bromadiolone treatment carried out in wheat field number 2 gave the highest benefit/cost ratio as the result of low percent cut tiller in the field. Similar studies in barley fields in Michew showed a loss of 169.26 kg/ha in untreated field which is equivalent to a loss of BR 202.80/ha. Bromadiolone treatments resulted in reduction of rodent damage with the amount of 169 kg/ha in each fields of barley (Table 6). The cost benefit ratio ranged between 1:8.9 to 1: 17.7. The bromadiolone treatment carried out in barley field number 3 gave the highest benefit/cost ratio because of low amount of labour and rodenticide used. The cost and benefit are calculated using the price of various inputs at the time of controlling rodents and the poison saved price is calculated using the price at the time of harvest, i.e. bait carrier. Birr 1.85/kg. Bromadiolone concentrate Birr 101.24; labour cost of formulation Birr 40/750 kg of finished bait; eight man hour for the treatment Birr 6; wheat Birr 1.50/kg.

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Table 1. Rodent control and number of trained farmers in Tigray

Zone	Woreda	Project site (Peasant Association)	Census techniques*	Percent reduction	Trained farmers
Southern	Endemoheni	Hanbahasti	1	100	107
		Meswaeti	2	100	238
			3	100	
				Mean 100	
	Enderta	Amanit	1	89	30
		Adimizan	2	100	25
			3	100	
				Mean 100	
Eastern	Gulomakeda	Mukaya	1	75	19
		Legat	2	90.7	
			3	63.6	17
				Mean 77.15	
	Ganta Afeshum	Betehariat	1	92.9	103
		Sasun	2	94.4	52
			3	81.9	
				Mean 88.12	
	Bizet	Rubashewit	2	78.1	70
			3	100.0	
		Tewahido		Mean 89.04	
			1		

Table 1. Contd.

Zone	Woreda	Project site (Peasant Association)	Census techniques'	Percent reduction	Trained farmers
Central	Doga Temben	Mulfa	2	86.9	45
	Endamariam		3	73.3	
				Mean 80.1	
		Mai-Berazio	1	84.6	200
			2	77.6	
			3	71.4	
				Mean 77.9	
Western	Laelay Koraro	Adikumelah	1	81.2	42
		Adigedena	2	82.6	35
			3	68.4	
				Mean 75.5	
	Adidaero	Kebabo	1	68.7	12
		Adierar	1	97.1	88
	Tsembla	Zenakoda	2	87.4	147
			3	76.5	
				Mean 81.91	1230

1. Active burrow counting method of census technique, calculated using the total number of burrows opened during pre and post treatment census periods.
2. Bait consumption method of census technique, calculated using the 3 days average consumption of pre treatment and post treatment census.
3. Tracking tiles activity method of census technique, calculated using the three days average number of positive tiles of pre treatment and post treatment census.

Table 2. Rodent control and number of trained farmers in Gondar and West Gojam

Zone	Woreda	Project site (Peasant Association)	Census techniques*	Percent reduction	No of trained farmers
South Gonder	Lay Gaint	Gobegob	2	86.87	129
			3	88.89	
				Mean 87.88	
					200
		Sali	2	92.12	
			3	78.57	
				Mean 85.34	
	Libo ke-makem	Abomeda	2	82.98	60
			3	81.63	
				Mean 82.30	
	Ebinat	Gunaguna	2	100	49
		Mechena	3	100	
				Mean 100	
		Debir	2	98.34	109
			3	100.00	
				Mean 99.12	
		Jima	2	98.82	61
			3	100.0	

Table 2. Contd.

Zone	Woreda	Project site (Peasant Association)	Census techniques*	Percent reduction	No. of Trained farmers
North Gondar	Debark	Miligebsa	2	88.02	53
	Dabat	Benker	2	98.46	60
			3	92.78	
				Mean 95.68	
		Wokin	2	90.46	67
			3	68.03	
				Mean 79.24	
West Gojam	Yilmana Densa	Korrie	2	96.8	74
			3	91.45	
				Mean 94.12	
		Mosabo	2	71.73	120
			3	83.50	
				Mean 77.52	
		Adethana	2	92.6	58
			3	97.0	
				Mean 94.8	

1 Active burrow counting method of census technique, calculated using the total number of burrows opened during pre- and post-treatment census periods.
2. Bait consumption method of census technique, calculated using the 3 days average consumption of pre treatment and post treatment census.
3. Tracking tiles activity method of census technique, is calculated using the three days average number of positive tiles of pre- treatment and post-treatment census.

Table 3. Total census bait consumption in pre-treatment, post-treatment and poison bait consumption in treatment periods (grams) in Tigray*

Project site	Pre-treatment	Treatment	Post-treatment	Treatment period (Days)
Meswaeti	3978	3005	0	1
Adimizan	1982	1719	0	15
Legat	2063	2137	160	15
Sasun	409	1711	23	15
Ruba Shewit	1070	6029	255	15
Mulfa	1143	1189	168	9
Mai-Brezio	925	2061	208	18
Adigedena	258	927.8	207	9
Zenakoda	3328	5379	405	15
Mean	1684	2573.04	158.6	13.7

Poison consumption is not recorded in sites where burrow plugging method of census technique is used, because poison cannot be recovered and weighed from burrows)

Table 4. Total census bait consumption in pre-treatment, post-treatment and poison bait consumption in treatment periods (grams) in Gondar and west Gojam*

Project site	Pre-treatment	Treatment	Post-treatment	Treatment period (Days)
Gbgob	3077	7723	404	21
Sali	2295	4023	181	21
Abomeda	2198	5992	374	21
Gunaguna	180	652	0	21
Mechena				
Debir	1209	930	20	21
Jima	433	1381	5	21
Miligabsa	1202	1058	144	9
Benker	1202	2351	18	15
Wokin	1563	1108	149	12
Korrie	1317	2118	42	9
Mosao	1942	5701	549	18
Adet Hanna	1268	46.77	94	15
Mean	1490.5	3142.56	165	17

* Poison consumption is not recorded in sites where burrow plugging method of census technique is used, because poison cannot be recovered and weighed from burrows)

Table 5. Economics of bromadiolone (0.005%) treatment in wheat fields of Global 2000 at Wikro (Tigray)*

Field No.	1	2	3	4	Check
Area (m^2)	5000	5000	5000	5000	5000
% cut tiller	1.25	0.89	3.25	3.72	6.90
Loss of grain (kg/ha)	28.08	20.74	58.68	124.23	203.13
Grain saved (kg/ha)	175.05	182.39	144.45	78.9	
Bait carrier (kg/ha)	6.61	5.88	4.9	2.94	
Bromadiolone oil concentrate (0.25%) (kg/ha)	0.14	0.12	0.10	0.06	
Labor cost of formulation (Birr)	0.36	0.32	0.26	0.16	
Man-hours for the treatment	4	3.55	3	1.83	
Cost of treatment (Birr/ha)	29.77	26	21.69	13.04	
Net benefit (Birr/ha)	232.80	247.56	194.98	105.31	
Cost: benefit	1:7.82	1:9.52	1:8.98	1:8.07	

Table 6. Economics of bromadiolone treatment in barley fields at Michew*

Field No.	1	2	3	4	Check
Area (m^2)	5500	1860	5772	4560	3472
% cut tiller	0	0	0	0	10.8
Loss of grain (kg/ha)	0	0	0	0	169.26
Grain saved (kg/ha)	169.26	169.26	169.26	169.26	
Bait carrier (kg/ha)	3.55	2.63	2.54	4.29	
Bromadiolone concentrate (0.25%) (kg/ha)	0.08	0.06	0.04	0.09	
Labor cost of formulation, (Birr)	0.19	0.16	0.14	0.23	
Man-hours for treatment/ha	3.6	5.8	2.6	4.38	
Cost of treatment (Birr/ha)	17.56	15.20	10.84	20.54	
Net benefit (Birr/ha)	185.25	187.60	191.96	182.26	
Cost to benefit ratio	1:10.55	1:12.34	1:17.70	1:8.87	

ENTOMOLOGY

Survey Results on the Wollo-Bush Cricket (*Decticoides brevipennis Ragge, Orthoptera, Tettigonidae*)

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Abstract

The Wollo-Bush cricket locally known as "Degezza" is an endemic crop pest to Ethiopia. Surveys conducted in 1993 and 1994 in North Shewa, Gojam, Gonder, Tigrai and Wollo showed that the insect is an important pest in the areas surveyed. The insect feeds mainly on tef and wheat and to a lesser extent on sorghum, noug and barley. In all the problem areas, the Ministry of Agriculture has been providing pesticides to the farmers for free. In Wadla Delanta, the history of the insect dates back to well over a century, but started becoming more serious some 70 years ago. Attention from the Government was paid first in 1974 when the areas experienced serious food shortage. Moreover, these areas are highly degraded and the rainfall is quite erratic. An entomopathogen was recorded in Enese Sarmidir. The ecology of the pest and its natural enemies need to be investigated in depth and appropriate technologies of control need to be developed for the immediate use.

Introduction

The Wollo Bush-Cricket (WBC) is a flightless long-horned grasshopper. It was first recorded as an important pest in 1968 when an outbreak occurred in Wadla Delanta District. Since then, several outbreaks of higher proportions were recorded in several places in Wollo including Wag, Lasta, Wadla Delanta, Wara Himanu, Wara Illu and Borena (Crowe, 1974). It was also recorded in North Shewa, East Gojam, South Gondar, Wollo and Tigray (Jaggo, 1977; Stretch et al., 1979). From 1974 to 1982 work on different aspects of the insect had been carried out by several authors: Ragge, 1977 on species description; Jago, 1977 on the ecology; Stretch et al., 1979 on the biology and control; Kemal, 1982 on chemical control.

The insect is known to have seven instar nymphs and the first three are completely black, the latter are light brown and the adults are brown. It feeds mainly on plants in the grass family and the most preferred are tef and wheat. It is flightless with low mobility. Its activity in its niche is favored by warmer temperature. In the Abay gorge, mating takes place in December (Jaggo, 1977; Stretch et al 1979). It has one generation in a year but hatching continues till the end of September (Jaggo, 1977). Fenitrothion ULV, Lindane

20% EC and 2% Dust were found effective against WBC (Stretch *et al*, 1979). Kemal in 1982 confirmed that dust formulation of lindane when applied using duster or pieces from Hessian sacks could effectively control the pest. Since 1982, no follow up work has been done on this endemic pest. Therefore, this study was conducted to study: its present status, its distribution and frequency of occurrence, the level of damage in different places, the number of outbreaks which occurred in the past, type(s) of control measures taken by farmers and the presence of natural enemies.

Materials and Methods

Field trips were conducted twice in 1993 in October and November to North Shewa, East Gojam, South Gondar, Tigray, North Wollo and South Wollo. In October 1994, a visit was made to "Gosh Meda" in North Wollo. In 1993, questionnaires were prepared and a total of fifty farmers were interviewed (Table 1). Direct field surveys were also conducted to confirm the presence of the insect in the areas where farmers were interviewed. Moreover, information were gathered from Woreda Ministry of Agriculture (MOA) staff who are directly involved on activities related to the insect. The woredas visited included Debre Libanos, Girrar Jarsso, Wara Jarsso in North Western Shewa, Dejen, Enese Sarmidir and Awbal in East Gojam, Tis Abay in West Gojam, Indaba Guna in Tigray, Sekota and Delanta in North Wollo and Debre Sina in South Wollo. Information were also collected from MoA staff of Abotte and Derra in North Western Shewa, Machakel, Bichena and Debre Work in East Gojam, South Gondar and Lasta in North Wollo. In 1994 field surveys, more than 4000 specimens were collected to identify diseased samples. The samples were collected in Delanta Woreda in a locality called Gosh Meda in a site called "Degezza Amba" which is named after the insect. In this place, an elderly farmer was also interviewed to find out more about the history of the insect.

Results and Discussion

Questionnaires and Direct Surveys. Twenty two woredas were identified to have WBC problem. But, it was possible to interview farmers only in eight woredas. The results of the questionnaire showed variation in the importance of the insect in the different woredas and damage on the major crops grown in the areas visited. The ecology of the WBC is characterized by having highland plateau and chains of mountains with scanty vegetation cover. Most of the places in the hill-sides are not suitable for farming, however, they have been under cultivation for several years. Rainfall is often short in the hilly sides which are preferred by the insect. Mixed farming is the major farming system in these areas. The major crops grown are tef, sorghum and wheat followed by barley, noug, maize, pepper, finger millet, faba bean, field pea, chick pea, grass pea and haricot beans. In the hill bottoms the only crops grown are tef, sesame, haricot beans and pepper. The insect prefers mostly tef and wheat. In Wara Jarso, Enese Sarmidir and Delanta the insect has also been observed by farmers feeding on wild grasses in the natural pastures (Table 2). Pasture lands in these woredas are very limited because of the need for more crop land to feed the increasing human population. The damage caused by the insect begins from grain filling period and is more pronounced from maturity till harvest. In some instances crops are attacked in the stacks.

Egg hatching, in some of the woredas starts early in July and in the rest in August. The peak populations of the damaging stages i.e. the late nymphs and the adults are synchronized with the heading and maturation periods of the preferred crops in the visited woredas (October-December) (Table 3). This increases the level of importance of the insect.

There have been many outbreaks in most of the woredas visited and the latest reported by the farmers were between 1984 and 1993 (Table 4). In all the woredas visited, different formulations of pesticides have been used to control the insect (Table 5). The farmers in Wadla Delanta and Enese Sarmidir also practice cultural methods to control the insect: (1) Some farmers clear the out-skirts of a farm and plow it and at times, they spread straws of tef and wheat on the peripheries and set it on fire. This practice deters the insect from interring crop fields. (2) If the insects manages to enter crop fields, farmers drive them out of the farm and kill them using physical means. These practices as sole methods cannot provide satisfactory control.

Yield Loss on Tef and Wheat. Attempts were made to estimate the yield loss caused by the insect in Degezza Amba. The yield loss was estimated to be between 15% and 35% on tef and 15% and 20% on wheat. When the terrain and the land holdings of individual farmers are considered, the losses incurred are quite substantial.

Degezza Diseases. Four diseased samples were collected in Enese Sarmidir in East Gojam and Gosh Meda in North Wollo. The first disease was recorded in Enese Sarmidir and its symptom was that the inside of the insect comes out through the exterior end of the body and later the insect dies. According to the development agents the disease was more common in the females. The second disease was recorded in Gosh Meda and the sample was associated with the deformation of the ovipositor. The third showed physical wounding of the mouth and exterior body parts. The fourth disease weakens the insects.

History of Degezza. From the discussions held with an elderly farmer[1] in Wadla Delanta, the insect had been around well over a century. The farmer reported that he had known the insect since childhood and the insect was recorded first in his locality in a place called "Degezza Amba" named after the insect. Degezza Amba means hill of Degezza. This name was given to the place because farmers for the first time observed the insect feeding and reproducing in this particular hill.

Though the insect had been there for a long time, it became economically important about 70 years ago when it caused 70-75% yield loss on tef and wheat and to a lesser extent on sorghum. Since then, the importance of the insect has been on the increase. The then government distributed pesticides for the first time in 1974 when the area experienced severe food shortage. Since 1974, the farmers in the area have been receiving insecticides free from the government every year.

1. Ato Mesfin Agegnehu was borne in Gosh Meda, aged 88, and has been farming in same place since 1935.

Conclusions

This survey has confirmed the increasing importance of the insect in its distribution areas. Considering the low productivity of the areas, the erratic nature of the rainfall especially in Wollo, the insect's high frequency of occurrence with repeated outbreaks and wider distribution over many places, the use of various classes of insecticides ranging from organochlorins to synthetic pyrethroids, the ever increasing human population which lowered tremendously land holding per family, it is high time that appropriate measure is taken to strengthen the studies on this endemic insect pest. The only pest with related morphological features, similar food habit and ecology is the "Mormon Cricket" which is a problem in Western United States. The importance, distribution and possible management methods had been studied for the "Mormon Cricket". The measures developed included use of physical barriers to halt the movement of the insect away from its hold over, use of dust and bait formulations of insecticides to prevent emigration to crop areas. Moreover, the most important measures taken was that the hold over areas of the insect had been mapped and surveyed every year in order to take measures that would help to prevent the coming together of small bands of the cricket and then reaching outbreak proportions, hence, reducing the potential damage to crops and rangelands. (Wakeland and Parker, 1952). Therefore, the same strategy need to be devised for the Wollo-Bush Cricket. Thus, the future studies should concentrate in the following areas:

- Strengthening the survey work for proper mapping of the insect ecology
- Identification and study on the natural enemies of the insect
- Developing better management methods to restrict its movement from its hold over
- Studying the biology of the insect in more detail

Table 1. Woredas and Localities from which farmers were interviewed and/or information collected about the WBC (Decticoides brevipennis Ragge)

Zone	Woredas	Localities visited	No. of Farmers Interviewed
North Western Shewa	Debre Libanos	Hagere Selam	9
		Zega Amel	
	Girar Jarso	Girar Jarso	
	Derra	----	
	Abotte	----	
	Wara Jarsso	Borso Kolla	9
		Gammo Kolia	
		Garmi Kolla	
		Gedara Kolia	
		Mojo Kolla	
East Gojam	Dejen	Gilgelle	7
		Kurar	
	Machakel	----	
	Awbel	----	
	Bichena	----	
	Debre Work	----	
	Enese Sarmidir	Demboza	5
		Emosse Ghiorgis	
		Mezgeb Yisaba	
		Ylmer Bona	
West Gojam	Tis Abay	----	3
South Gondar	Este	----	
	Ibinat	----	
	Lay Gayent	----	
	Libo Kemkem	----	
	Tach Gayent	----	
	Simada	----	
North Wollo	Sekota	Wolene Mariam	2
	Dawnt	------	
	Delanta	Alemu Irgata	15
		Atkena Selana	
		Dehna Kolla	
		Gosh Meda	
		Tikurena	
South Wollo	Debre Sina	----	
Total	22(8*)	21	50

* The fifty farmers were interviewed only in eight woredas

Table 2. Grass Species in The Natural Pasture Preferred by the WBC (*Decticoids brevipennis Ragge*)

Local Name	Scientific Name
Gaja	*Andropogon* spp.
Muja	*Snowdenia*
Senbelet	*Hyparrhenia* spp/
Serdo	*Cynodon* spp.

Table 3. Egg hatching period and peak months for the damaging stages (Instar IV and above) of the WBC (*Decticoides brevipennis* Ragge)

Zone	Woreda	Egg Hatching Begins	Peak Period For Damaging Stage
North Shewa	Wara Jarsso	August	Sept to Oct
East Gojam	Enese Sar Midir	August	Sept to Oct
	Dejen	August	Sept to Oct
North Wollo	Dawnt	July	Sept to Dec
	Delanta	July	Sept to Dec
	Sekota	July	Sept to Dec
South Wollo	Debre Sina	August	Sept to Dec
South Gondar	In All	July	Sept to Nov

Table 4. The latest Five Years of the WBC (*Decticoids brevipennis* Ragge) Outbreaks in the visited woredas as reported by farmers

Woreda	Out break years
Wara Jarsso	1985 & 1990-92
Dejen	1989-92
Enese Sarmidir	1989-93
Sekota	1989-93
Delanta	1989-93
Debre Sina	1989-93

Table 5. The number of Zones, woredas and Localities, the type and Amount of insecticides used for the WBC (*Decticoids brevipennis* Ragge) Control in 1992

Zone	Woreda	Sprayed Localities	Pesticide*		Area (ha)
			Name	Amount	
N.Shewa	W. Jarsso	10	Diazinon EC	30	30
			Endosulfan EC	60	60
E. Gojam	Awbale	4	Carbaryl WP	3.5	3.5
	Dejen	6	Diazinon EC	54	44.5
			Dimethoate EC		
			Endosulfan EC		
	Enese Sarmidir	21	Bendiocarb EC	243	886
			Carbaryl WP	88	(1789)*
			Diazinon EC	226	
			Dieldrin EC	60	
			Fenitrothion EC/ULV	180	
	Machakel	20	Carbaryl WP	----	
			Fenitrothion EC		
N.Wollo	Dawnt	23	Carbaryl WP	225	1792
			Dimethoate EC	545	
			Ekatin EC	528	
			Lindane Dust	160	
			Malathion EC	400	
	Delanta	18	Carbaryl WP	50	897.5
			Dimethoate EC	415	
			Ekatin EC	415	
			Lindane Dust	450	
			Malathion EC	260	
S. Wollo	Mekane Selam	59	Dimecron EC	469	586
			Fenitrothion EC	50	
			Phosphamidon EC	40	

*Total Area Infested by the WBC
Source: The Respective Woredas MoA Offices
Amount is either in Kg or lt.

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Seasonal Occurrence of the Sorghum Shoot Fly (*Atherigona soccata*) on Sorghum at Ambo

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Abstract

Seasonal occurrence of the sorghum shoot fly (*Atherigona soccata*) at Ambo was studied over a period of three years (1992-1994) both in the main and off seasons by planting a susceptible variety IS-9302 at monthly intervals. At twenty five days interval after seedling emergence, the number of total plants and those with deadheart symptom were recorded. Percentage of deadheart occurrence was analyzed in relation to monthly rainfall and daily average temperatures. It was found out that in the presence of a suitable stage of the host, *A. soccata* would be present throughout the year reaching peaks towards the end of March (42.2%), late September (83%) and mid-October (57.8%). It was also noted that at peak periods of A. soccata infestation, 15% seedling attack occurred for a short period of time by another species of shoot fly known as *Diopsis* sp. Nevertheless, statistically significant relationship was not found between the monthly fluctuation of the pest and meteorological data.

Introduction

The sorghum shoot fly (*Atherigona soccata* Rond.) is one of the major insect pests of sorghum in Ethiopia (4). The larva destroys the growing point of seedlings and causes a characteristic "deadheart" which results in low plant population, profuse tillering, uneven maturity and failure to form harvestable heads (1). Damage severity varies considerably from season to season and year to year though late-sown crops are generally attacked more severely (2).

Determination of the seasonal occurrence of the sorghum shoot fly is important to avoid coincidence of the peak insect population with the most susceptible stage(s) of the crop. It also helps determine the time of application of chemicals for effective control of the pest. In varietal screening work also, this information can be used to ensure that the peak pest population coincides with the most susceptible stage(s) of the crop thus helping in effective screening.

Consequently, this study was initiated to determine the seasonal occurrence of the sorghum shoot fly and the climatic factors responsible for its incidence under Ambo conditions.

Materials and Methods

Shoot fly infestation on sorghum seedlings at Ambo was monitored by planting a susceptible variety (IS-9302) at monthly intervals from 1992-1994. The experiment was conducted both in the main (kiremt) and the off season using irrigation. Seasonal incidence of the fly was determined by counting the total number of plants and those with deadhearts at twenty five days interval after crop emergence. Percentage of deadheart was computed by taking the proportion of deadheart count to the total number of plants. During peak periods of shoot fly attack, 20 plants randomly selected were dissected to determine the species composition of the pest.

Meteorological data (temperature and rainfall) obtained from the Ambo Meteorological station (Ca.2 kms from the experimental field) were correlated with deadheart counts.

Results and Discussion

A relatively low level of seedling attack occurred in 1994 just before the long rain of kiremt (April to July). The activity of the fly began to increase starting from the second week of August onwards reaching the highest peak in September and October. In 1992 and 1994, a peak of 60% and 83%, respectively, deadhearts were noted in September. In 1993, the maximum number of deadhearts occurred in October with 57.8% of the seedlings attack. Beginning from November, the level of attack decreased gradually with the progress of the dry season.

Irrigated sorghum seedlings were also observed to suffer from shoot fly attack starting from the end of February and reaching a peak in March (42.2%) during the off-season in 1994.

It was also noted that seedling injury was aggravated for a short period, by another species of shoot fly known as *Diopsis* sp. During peak periods of shoot fly incidence (deadhearts), 15% seedling attack was ascribed to *Diopsis* sp.

Environmental factors prevailing 7-20 days after crop emergence are assumed to affect the formation of deadhearts for a particular count (1). The correlation between the environmental factors and the formation of dead hearts showed no significant correlation in most cases. In one instance, however, the negative correlation between deadhearts and the daily minimum temperature in 1993 was found to be significant (Table 1).

This study has revealed that shoot fly is not a pest of early-sown sorghum. Therefore, sorghum planted in the beginning of the cropping season (April-May) under Ambo conditions, can escape the damage that can be inflicted by the sorghum shoot fly. On the contrary, sorghum planted between August and September suffers maximum deadheart injury. This information can thus be used to adjust the time of effective and reliable varietal and/or chemical screening work against shoot fly.

Table 1. Relationships between shoot fly incidence (deadhearts) and environmental factors at Ambo PPRC, 1992 to 1994.

	Correlation coefficient (r)			
	1992	1993	1994	1992-1994
Deadhearts Vs:				
RF	-0.326	-0.283	-0.251	-0.300
MXT	-0.625	-0.137	-0.232	-0.239
MIT	-0.741	-0821*	0.044	-0.130
DAT	-0.712	-0.333	-0.306	-0.219-

RF = Rainfall; MXT - Daily Maximum Temperature; MIT = Daily Minimum Temperature; DAT - Daily Average Temperature; for $p < 0.05$

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Loss Caused by the Stalk Borers, *Chilo partellus* (Swinhoe) and Busseola fusca (Fuller), on Sorghum in Central Ethiopia

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Abstract

Experiments were carried out at Adamitulu Research center of IAR in 1992 and at Zway Research Center of the Awassa College of Agriculture in 1993 to determine the loss caused by the stalk borers, *Chilo partellus* (Swinhoe) and *Busseola fusca* (Fuller), in sorghum. In a factorial RCBD with split plots using two varieties, 76 T1 # 23 and Seredo, as main plot treatments and application of insecticide, cyhalothrin 16 g a.i./ha, at different times of crop growth, yield losses of 64.4% (2.09 tons ha^{-1}) at Zway and 23.6% (0.4 tons ha^{-1}) at Adamitulu were recorded. Application of the insecticide at 45 days after crop emergence (DAE) resulted in significantly low damage and gave higher yield compared to applications at 15 or 30 DAE. Significant difference was not observed between main plot treatments.

Introduction

Lepidopterous stem borers, *Chilo partellus* (Swinhoe) and *Busseola fusca* (Fuller), are important pests of sorghum in Ethiopia as they are in other African countries. *C. partellus* is the dominant species at lower altitudes whereas *B. fusca* is dominant at higher altitude (1160 - 2500 m) and cooler areas of the country (Assefa, 1985). Both species can be found together in mid-altitude areas (1200 - 1700 m) (Tessema, 1982). The borers attack the crop throughout its growing period. However, like insect pests of many other crops, stalk borers attack become economically damaging depending on time of attack in relation to crop phenology and pest population. Based on applications made at four and six weeks after crop emergence, cyhalothrin 16 g a.i./ha was reported to be effective against *C. partellus* in sorghum in Ethiopia. However, information on yield loss due to stalk borers attack in sorghum and susceptible stages that would result maximum yield loss was lacking although Melaku and Gashawbeza (1993) reported 15 DAE as susceptible stage based on pre harvest data. Losses on sorghum by one or both species is variously reported by different workers. A yield loss as high as 70.8% (Taneja and Nwanze 1989) and 56% (Starks, 1969) is reported on sorghum due to *C. partellus* attack. Critical period of damage is also variously reported as 15-30 DAE on sorghum (Taneja and Nwanze 1989), 10 - 17 DAE on maize (Sarup *et al.* 1977) and 30 - 45 DAE on maize (Assefa and Tessema 1982). This experiment was therefore conducted to estimate the loss caused by the stalk borers, *C. partellus* and *B. fusca*, and to know the critical stage of infestation that results in maximum yield loss in sorghum in Ethiopia.

Materials and Methods

The experiment was conducted at Adamitulu (1650 m a.s.l) in 1992 and at Zway (1650 m.a.s.l) in 1993 in a factorial RCBD with split plots using two varieties, 76 T1 # 23 and Seredo, as main plot treatments and seven different chemical protection levels applied at different times of crop growth as subplot treatments. The seven subplot treatments (chemical protection levels) were: chemical applied at 15 DAE; (2) at 30 DAE; (3) at 45 DAE; (4) at 15, and 30 DAE (5) at 30, and 45 DAE; (6) at 15, 30, and 45 DAE; and (7) no protection. The varieties were planted at Adamitulu (and Zway) on 10 July (and 17 July). The crop emerged on 21 July (and 28 July); thinning was made maintaining plant spacing of 15 cm. Plot size was four rows each five meters long (3 m 5 m). The insecticide cyhalothrin 5% EC reported to be effective (IAR 1988) for the control of C. partellus was applied at the rate of 16 g a.i./ha i.e. 0.48 g of the product per plot using knapsack sprayer at 15 DAE on 6 July (and 12 July), at 30 DAE on 20 July (and 27 July) and at 45 DAE on 3 August (and 12 August). The following observations were made before harvest from the central two rows of each plot: stand count at emergence, number of plants with leaf damage fortnightly after crop emergence, leaf feeding score on a 1 - 9 scale (1 = low, 9 = high) and dead hearts at 30 and 45 DAE. At harvest number of stalks, number of stalks with stalk borer damaged chaffy heads, number of harvestable heads and yield were recorded from the central two rows of each plot.

Results and Discussion

Differences between varieties and their interaction with time of insecticide application were not significant at both locations in all the characters measured although Seredo appeared to be more susceptible. For example, the mean percent of leaf damage at 60 DAE, percent chaffy head, percent peduncle damage and yield (Kg/ha) at Adami tulu in the variety Seredo were 24.5, 20.3, 64.5, and 1307 respectively compared to 25.5, 12.5, 59.6, and 1853 in the variety 76 T1 # 23.

Results of the experiment carried out at Adamitulu are presented (Table 1 & 2); differences among treatments were significant in most of the variables measured. Percentage of plants with leaf damage at 30 DAE was low in all plots sprayed at 15 DAE and high in the rest. The magnitude of leaf damage at 45 DAE remained high in plots sprayed only at 45 DAE and in the untreated plots; slightly increased in plots sprayed only at 15 DAE and decreased in plots treated at 30 DAE. At 60 DAE, plots sprayed at 45 DAE had significantly low percentage of leaf damage (Table 1 & 2). The 'dead-heart' observed at 30 and 45 DAE was not high and it was due to shoot fly, *Atherigona soccata* (Rond.) attack. The average percentage of dead heart were 13.2 $\pm$ 1.45 and 2.14 $\pm$ 0.42 at 30 and 45 DAE respectively. The percentage was low in plots treated at 15 DAE and high in the rest. The minimum and maximum percentage of 'dead-heart' in plots that received the insecticide at 15 DAE ranged from 4.6 - 7.1 and 0.2 - 1.5 at 30 and 45 DAE respectively.

In contrast, it ranged from 16.7 - 19.7% and 1.5 - 5.8% at 30 and 45 DAE in plots that didn't receive the insecticide at 15 DAE. Leaf feeding score at 30 and 45 DAE was low and differences were not significant among treatments; however, it was high and significant difference were observed at 60 DAE. As can be seen in Table 1 & 2 it was significantly low in plots that received the insecticide at 45 DAE and high in the untreated plots and plots sprayed only at 15 DAE. Significantly high damage in percent chaffy head and peduncle damage was observed in the untreated plots and in plots that were not sprayed at 45 DAE (Table 1 & 2). All the plots that received the insecticide at 45 DAE gave better yield than the rest of the treatments. The difference in yield between a particular treatment with the untreated check indicated a yield loss as high as 23.6% (0.4 tons ha^{-1}; this loss was observed by comparing with the yield of the plots treated at 30 and 45 DAE. Results of the experiment carried out at Zway, in 1993 is presented (Table 3). Similar pattern in infestation and damage was observed to that of the 1992 data. Significantly low damage and higher yield were recorded from plots that received the insecticide at 45 DAE. Differences in terms of infestation and yield loss was not significant between once application at 45 DAE and three times application (15, 30, and 45 DAE) whereas differences between once application at 15 DAE or 30 DAE with 45 DAE was significant (Table 3). The lowest grain yield (1080 Kg ha^{-1}) was recorded from the untreated plots whereas the highest yield (3030 Kg ha^{-1}) was recorded from the intensively treated plot; this difference indicates a 64.4% (2.09 tons ha^{-1}) avoidable loss in grain yield. Percent leaf damage and leaf feeding score was consistently low in the intensively treated plot, gradually increased in plots sprayed at 15 DAE only and remained high in the untreated plot. However unlike the 1992 data percent leaf damage at 60 DAE in plots sprayed only once at 45 DAE was not significantly different from the untreated plot although differences in leaf feeding score was significantly low compared to the untreated check (Table 3). Percentage of dead heart at this location was too low to make comparisons. The highest percentage of dead heart was 2.78 at 30 DAE and 2.2 at 45 DAE. Although larval count was not made to determine the species composition of the two stem borers in this experiment, their composition at Zway with similar altitude (1650 m.a.s.l.) and environment to that of Adamitulu was 6.8 and 93.2% respectively as observed on a sowing date experiment planted in the same season.

This study indicated that Stalk borers can cause a yield loss as high as 64.4% in mid altitude areas of central Ethiopia. As observed infestation in terms of leaf damage and leaf feeding score was low in plots protected during the early stage of crop growth. Infestation at this stage is the result of the first generation attack. Second generation moths infest the plants between 45 - 55 DAE; first instar larvae infest the whorl, the second and third instars move one or two internodes below the whorl and enter the stem usually at the leaf axil. On feeding, the head may lodge on the peduncle, or damage on the vascular tissue will produce partial or complete chaffiness. Low percentage of stalk borer damage in terms of chaffy head and peduncle damage and hence an increase in harvestable head and grain yield in plots sprayed at 45 DAE was the result of the control of infesting larvae of the second generation moth. From sowing date experiment on maize against the maize stalk borer, *B. fusca*, a yield loss ranging from 22.5 - 100% due to attack by the second generation moth while only 0 - 22.6% due to first generation attack has been reported in Ethiopia by Assefa *et al.* (1988). Several workers reported different effective protection period of stalk borers. Grewal (1969), Chatterji et al. (1972) and Sharma *et al.* (1973) reported 15 - 34 DAE as critical period of attack. Taneja and Nwanze (1989) stated that maximum control of stem borer infestation in sorghum was obtained when the crop was protected between 15 - and 30 DAE by application of insecticide granules in leaf whorls. Melaku and Gashawbeza (1993) reported early stage protection (15 DAE) as critical period using pre-harvest data. Assefa and Tessema (1982) reported that the best time of insecticide application against maize stalk borer, *B. fusca*, on maize at Awassa, Ethiopia, was four to six weeks after emergence. As pointed out earlier our previous report on susceptible stage of sorghum to *C. partellus* attack based on a year observation did not include data at harvest; it was based on mean percent of leaf damage and leaf feeding score. The correlation analysis in the present experiment indicated that yield loss did not correlate with damage at the early stage of crop growth. For example, correlation of leaf damage at 30 and 45 DAE with yield was (r = 0.096, P = 0.483) and (r = 0.014, P = 0.917) respectively in 1992 where as correlation between leaf damage at 60 DAE with yield was negative and significant (r = -0.400, P = 0.002). The correlation between damage at harvest and yield was also negative and significant. This indicates the importance of the second generation moth in sorghum similar to reports on *B. fusca* attacking maize (Assefa et. al., 1989; Assefa and Tessema, 1982). Yield loss on a crop by a particular pest is the result of several factors: location, insect species, variety, season, cropping system etc. It is therefore necessary to carry out similar experiment in different locations where the crop and the pest are important to develop appropriate control measures.

Table 1. Effect of cyhalothrin applied at different period of sorghum growth on stalk borers, C. partellus and B. fusca, infestation and damage at Adamitulu, 1992

Applied at (DAE)	% leaf damage 60 DAE	Leaf feeding score 60 DAE	% chaffy head	% peduncle damage	% harvested head	Yield (Kg/ha)
15	42.9	5.6	33.2	81.7	54.3	730
30	23.9	3.8	23.8	72.5	62.3	1048
45	1.3	1.0	5.3	41.4	80.3	1498
15 & 30	22.6	3.9	19.8	81.2	71.3	1255
30 & 45	0.0	1.0	4.3	41.8	81.8	1690
15, 30 & 45	1.8	1.0	10.6	38.7	74.7	1332
Untreated	47.3	5.8	17.7	77.1	69.7	1289
Mean	20.0	3.1	16.4	62.0	76.6	1263
SE	3.1	0.3	2.2	3.0	2.0	76.6
CV (%)	71.0	38.4	72.4	18.0	17.7	28.4
LSD (0.05)	14.4	1.2	12.0	11.3	12.7	364.0

Table 2. Effect of cyhalothrin applied at different period of sorghum growth on stalk borers, C. partellus and B. fusca, infestation and damage at Adamitulu, 1992.

Applied at (DAE)	% leaf damage (DAE)			Leaf feeding score	% chaffy head	% peduncle damage head	Yield (Kg/ha)
	30	45	60				
15	2.6	10.7	42.9	5.6	33.2	81.7	730
30	17.2	10.7	23.9	3.8	23.8	72.5	1048
45	17.9	22.3	1.3	1.0	5.3	41.4	1498
15 & 30	0.9	3.1	22.6	3.9	19.8	81.2	1255
30 & 45	12.7	8.3	0.0	1.0	4.3	41.8	1690
15, 30 & 45	1.2	3.8	1.8	1.0	10.6	38.7	1332
Untreated	11.6	17.6	47.3	5.8	17.7	77.1	1289
Mean	9.2	10.9	20.0	3.1	16.4	62.0	1263
SE	1.4	1.3	3.1	0.3	2.2	3.0	76.6
CV (%)	72.4	59.0	71.0	38.4	72.4	18.0	28.4
LSD (0.05)	6.7	6.5	14.4	1.2	12.0	11.3	364

Table 3. Effect of cyhalothrin applied at different period of sorghum growth on stalk borers, C. partellus and B. fusca, infestation and damage at Zway, 1993.

Applied at (DAE)	% leaf damage 60 DAE	Leaf fee-ding score 60 DAE	% chaffy head	% harvested head	Yield (Kg/ha)
15	40.0	1.5	26.6	73.9	1495
30	39.7	1.4	25.4	74.6	1736
45	47.3	1.4	13.2	86.3	3030
15 & 30	29.2	1.0	31.6	65.4	1519
30 & 45	38.8	1.0	10.3	87.9	2640
15, 30 & 45	26.1	1.0	8.2	88.1	3172
Untreated	51.4	2.1	40.3	58.0	1080
Mean	38.9	1.3	22.2	76.4	2096
SE	2.55	0.08	2.65	2.58	151.1
CV (%)	40.8	34.2	54.8	16.2	42.6
LSD (0.05)	16.1	0.5	12.4	12.6	904

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Insect Biosystematic Services in Africa, with Emphasis on the Current Status and Future Prospects in Ethiopia

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Abstract

The recent history of initiatives in support of tropical insect taxonomy and the current status of the insect collection resources of Africa, are reviewed with emphasis on the establishment of a national insect reference collection in Ethiopia. The need for establishment and future development of a national collection as a center of insect biosystematic services, training and research is stressed. Specific suggestions are presented for the future development of such center which focuses on the improvement of facilities and budgetary allocation for insect collection and taxonomic research in Ethiopia. Man-power training at different levels is also emphasized to implement such plan.

Introduction

More than half of the world's species of living things are insects (Blackman, 1995) most of which are definitely in the tropics placing insect taxonomists under some pressure in describing new species. Although the tropics is rich in biodiversity, taxonomists have often been rare in this part of the world. Classical taxonomy is usually considered an empirical science which simply involves naming and describing species and arranging taxonomic categories. Modern systematics involves much more than simply naming and describing species such as ecology, cytology, biometry, evolution, and genetics.

Biosystematics is recognized to play a vital role in the orderly exploitation of the renewable natural resources which are essential in agricultural development and in programs to improve human and animal health. This fact is further strengthened by Obe (1994) in his statement addressing the global biosystematic crisis by saying "...the present biosystematic impediment to biological research is the biggest single scientific constraint to human aspirations for sustainable and the wise use of biodiversity". Insect biosystematics is, without doubt, the most important fundament to biological control and a key to all other fields of research related to Insect pest management. This paper emphasizes the long overdue need for a strong and concerted effort to raise the profile of insect biosystematics in Africa in general and in Ethiopia in particular as narrow and piecemeal approaches will not attract the attention and financial support of governments and donor organizations.

It is generally acknowledged that there is a growing need for biosystematic services in Africa to serve programs of applied entomology in agriculture, forestry, and human and animal health as well as in investigations of natural ecosystems concerned with impact assessment and biodiversity. The size, complexity and poor state of knowledge of tropical faunas exacerbates this problem (Ritchie, 1987).

There has been several occasions where discussions among biologists stressed the need for improved funding for biosystematics in the tropical world, especially in Africa. Until recently the position has been characterized more by discussion and promise than by positive action as many recommendations forwarded brought little discernible change in the status of insect taxonomy in Africa. Since 1990's especially after the Rio Conference on biodiversity in 1992, biosystematics seem to have received the attention of donors more than it has before. There are also research grants such as the EARTHWATCH Europe in biodiversity which includes faunal and floral diversity studies as one aspect of biosystematics and BioNET INTERNATIONAL, which is a global network concerned particularly with the biosystematics of invertebrates and microorganisms.

So far support for taxonomic research and services has been stressed but what efforts and achievements have been made by Africa? Sadly enough not much. Some of the reasons may be (1) lack of recognition and support for the field from national Institutes, governments and professionals (2) limited job opportunities in the field (3) poor pay and (4) the field is challenging as the end should be precise (correct taxonomy/identification). Professional societies like the Crop Protection Society should play an active role in creating awareness and overcoming some of the problems.

Status of Insect Taxonomy and Reference Collections in Africa

In Africa about 70% of the insect species and 40% of the genera are thought to have not been named. About 70% of the parasitic Hymenoptera are undescribed and for 97% of the described species their biological information is not known or studied (Personal communication). Lack of revisionary work in Africa is also a problem as evidenced by the cowpea pest which is known by two names in west and east Africa i.e. *Acanthoma horida* and *Clavigralla shabadi*.

Regarding Africa's inventory of insect collection resources, many countries have one or more small collections housed in institutions dealing with plant protection or quarantine, or occasionally in museum, maintained by a technician with many other responsibilities and no specific training. An overall survey of taxonomic services in Africa and recommendations to select potential regional reference centers were made by a committee set by the African Association of Insect Scientists although no significant achievement has been made since then (Akingbouhungbe, 1981). The status of the Insect Reference Collection of about a dozen African countries with a significant size of insect collection is presented in table 1.

Status of Insect Taxonomy Services in Ethiopia

The broad range of genetic diversity existing in Ethiopia is not only limited to plants but also applies to insects as there has been a co-evolution of species of plants and most insects. Unlike the impressive efforts being made in systematic Botany, however, no appreciably consistent work is done with regard to insect systematics in Ethiopia. This is a painful fact to accept for the entomologist since having a good national insect reference collections is equivalent to having a good library of insect fauna of a country.

The scattered small reference collections in Ethiopia appear to have no trained insect taxonomist who works as a curator. There also exists information gap among these few local centers making it difficult to know which-has-what unless one goes to these centers. Worse even, in some of the local collection centers properly documented inventory of the collections are not available. Hence, one may have to check the cabinet drawers to see what is in there from the labels on the specimens. Currently the development of these reference collections is stagnating. As it would be an expensive venture to keep or maintain specimens longer, collection enters should not be established in warm and humid areas. Institutions which have the facilities and manpower should take the lead in establishing such collection centers at appropriate locations in order to cover the country's diverse agroecological zones evenly. The representativeness and the viability of the formerly established small centers should be thoroughly revised with the aim to strengthen them or move them to areas which are appropriate. Concomitantly, progressive measures to establish the national insect reference collections should be taken. It must be understood that a good national reference collection exists only when there are strong local/regional collection centers.

Our country also lacks the tradition of exchanging specimens locally for identification and the country is yet to have a senior insect taxonomist who can establish and lay down the foundation for a taxonomic research program.

Suggestions for Future Improvement

Based on the foregoing remarks there is a need to work hard and improve the current status of Insect Biosystematic services in our country. There are now clues for a positive attitude from the international communities in obtaining fund for biosystematics. Although the situation seems encouraging we should, however, take concrete steps to improve our own conditions in our own capacity. These are:

- Setting up a National Insect Reference Collections
- Improvement of the infrastructure & facilities for collection, management and taxonomic research
- Strengthening the existing local (regional) collections and establishing new ones in areas where they do not exist.

- Provision of training opportunities at all levels (from certificate up to PhD.) both in the country and abroad.

- Budgetary allocation for a taxonomic component in entomological research projects and advance liaison between users of identification services in such projects and the taxonomists who give them service.

- Establishment and development of taxonomic research program

- Inception of a regional (continental) identification service for insects of agricultural importance

- Setting up of computerized databases to give easier access to the information contained within the National and if possible regional collections

As developing countries have become increasingly aware of conservation of biodiversity for sustainable use, their need for biosystematic services increased accordingly. On the other hand, due to the economic recession in most of the developed countries, world centers and suppliers of biosystematic services imposed charges which are beyond the foreign exchange capacity of most developing countries.

We may not be in a strong position to National Insect Reference Collections in Ethiopia very soon. However, a continued commitment is needed from national Institutes, professionals and the government to lay down the foundation and maintain a viable core of facilities and expertise. As Obe (1994) suggested, for the developing countries to be self-reliant in biosystematics, the leadership must come from ourselves through concerted Do-It-Yourself programs with sustainability. Effective mechanisms for institutional collaboration for rational use of existing resources, and their subsequent enhancement through capacity building and human resource development programs must be facilitated by national governments and the international community. Our basic capability can be supplemented through a network of active international contacts through externally funded projects and personnel providing support an in-country training for indigenous specialists.

The development of biosystematic services provides not only the inventory and interpretation of the biological diversity of our country but also ensures the application of biosystematic science to the pressing problems of environmental conservation and the protection of our health and resources from insect attack. We need to explore the faunal diversity of the insects in our country without delay as the effort could be of paramount importance to our future development.

Table 1. The insect reference collections in some of the African countries

Country	No. of specimen	No. of species	Location and source*
1. North Africa			
Egypt	100,000	5,600	Plant Protection Institute, MOA (6)
			Entomological Society of Egypt (6)
	70,000	4,000	
			Cairo University Faculty of Science (6)
	70.000		
2. West Africa Senegal (NIRC)	> 100 000		Institute Fundamental D;Afrique Noire (IFAN) DAKAR (7 & 10)
Nigeria (NIRC)	> 10,000 in 50 cabinet drawers		University of Ibadan (personal communication)
			University of Ife. Natural History Museum (10)
			Institute of Agricultural Research, Ahmadu Bello University, Samaru (4 & 10

Table 1 contd.

Country	No. of specimen	No. of species	Location and source*
Ghana	-	-	University of Ghana a Legon (personal communication)
3. Southern Africa South Africa (NIRC)	5,600 cabinets and 3,500 spirit collection i.e. >5,000-,000	-	Plant Protection Research Institute Pretoria (9)
Malawi	20,000	3000	Bvumbwe Agricultural Research Station LIMBE (5)
	20000	-	LILONGWE, ZOMBA & THONDWE (5)
	>18000	4000	Chancellor College (5)
Zimbabwe (NIRC)	3000 cabinet drawers	-	Bulawayo(3)

Table 1 contd.

Country	No. of specimen	No. of species	Location and source*
Mozambique (NIRC)	250,000	-	Museu de Historia Natural, MAPUTO (10)
Nambia (NIRC)*	4,400	-	LIVINGSTONE (10)
4.East Africa Kenya (NIRC)	2,000,000	about 10,000	National Museums of Kenya, NAIROBI (personal comm., (10 & 11)
Ethiopia		about 1500	IAR, Holetta
	about 1000	267	AUA
	-	-	AAU
	-	-	MOA (personal comm. & 10)

NIRC indicates countries with national Insect reference Collection.
Sudan, Somalia and Central African countries such as Angola, Zaire and Cameroon are known to have small reference collections but the sizes are not known.

* = figures in parenthesis indicate sources of information.

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Some Laboratory Observations on the Biology of the Maize Weevil, *Sitophilus zeamais* Motsch. (*Coleoptera: Curculionidae*) at Bako

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Abstract

A preliminary study was made on the biology of the maize weevil, *Sitophilus zeamais* Motsch., in the laboratory at Bako Research Center; at room temperature and r.h. conditions. Cleaned and disinfested maize seeds (variety Bako Composite) was used as a medium. One male and one female weevil (1-8-day-old) were placed in a glass jar 350 ml capacity containing 40 to 50 kernels and replicated 15 times. Each pair of adults were transferred every 24 hrs into a new jar containing fresh kernels until the females died. Dead males were replaced by other males of the same age from a reserve culture. The female maize weevil produced progeny ranging from 1.24 to 2.48 per day and 121.86 $\pm$ 23.18 per female on the average. The pre-oviposition period was about 3 days. It remained fecund throughout its lifetime but the effective egg-laying period was about 50% of the life span. Upto four eggs were laid in a single maize kernel. The sex ratio of the maize weevil was about 1:1. Female weevils lived longer than male weevils. Maximum number of progeny emerged within 41-45 days, the average development period being 42 days. The development time of male weevils was sorter than that of female weevils, although the difference was not significant.

Introduction

Maize weevil, *Sitophilus zeamais* Motsch., is an important pest of maize and other cereals in Ethiopia. At Bako, Western Shoa where maize is the major cereal crop, it is the most important primary pest of stored maize (Abraham, 1993). Modern pest control demands extensive knowledge of pest biology and ecology. However, in Ethiopia, the biology of the maize weevil has not been studied to date. The objective of this study was, therefore, to obtain preliminary information on the biology of the maize weevil under Bako conditions.

Materials and Methods

The first step in this experiment was to produce weevils of known age following the rearing procedures of Wright, Mills and Willcutts (1989). About 50 kg of maize grain (variety

Bako Composite) was cleaned and stored in a freezer at -3°C for three to five weeks to eliminate possible contamination by undesirable insects. Then the grain was placed in plastic bags and allowed to acclimatize to the rearing room conditions for at least a week before use. The moisture content of the grain was adjusted to 12.5-13.5%.

Adult weevils were collected at random from infested maize at Bako Research center (BRC) farm grain store and cultured on cleaned and disinfested maize in seven replications. Each replication contained 300 weevils per 500 g of grain in a tin (17.5 cm diameter and 19 cm height) with lid. Ventilation was provided by screen opening in the lid. These cultures were kept at room temperature and relative humidity (r.h.) (Table 4). After 7 days of oviposition period all weevils were discarded and the grain was kept for emergence of progeny that was used in the subsequent experiments. Newly emerged adults were collected daily and kept in separate glass jars (350 ml capacity) by age group.

For the experiment 40 to 50 kernels of the medium were placed in 15 glass jars. Adult weevils were sexed based on their snout characteristics (TDRI, 1984) under a binocular microscope. Kernels in each jar were infested with one male and one female of 1-8-day-old adults. Each pair of adults were transferred to fresh kernels in a new jar every 24 hours for 15 weeks, until all females were dead. Each day dead male weevils were removed and replaced with males of the same age from the reserve cultures.

Newly emerged weevils were removed, counted, and sexed on their emergence day. Daily and total productivity of female weevils (given as no. of emerged adults and not as the actual number of eggs laid), number of days required for adult emergence, duration of oviposition, adult longevity, number of holes per kernel and parts of kernel holed were recorded. Daily minimum and maximum temperature and relative humidity were measured using a thermohygrograph. The room was kept at a dark and light cycle of 12 hr.

Results and Discussion

The female weevil remained productive for an extended period of its life time. However, the productivity was interrupted for a few days between successive oviposition periods. The effective oviposition time of a female weevil, i.e. time in the life span of the female when eggs were actually laid, was nearly 50% of its mean life span (Table 1). Oviposition started about 3 days after the emergence of the ovipositing female. Egg laying continued upto a mean time of 5 days before the death of the ovipositing female.

Oviposition by the maize weevil continued over a period of many weeks confirming the reports by Appert (1987) and TDRI (1984). TDRI (1984) indicated that adult weevils are long-lived and eggs are laid throughout most of the adult life.

A female weevil produced 61.4 male and 60.4 female progeny on the average; the production per female per day ranging from 1.24-2.48. The sex ratio was about 1:1 (Table 1). The number of adults produced (121.86 $\pm$ 26.18) per female in this study was 80% of the number of eggs reported (150 eggs per female) to be laid by the maize weevil (TDRI, 1984). Baker and Mabie (1973) found that on a meridic diet at 32°C and 65% r.h. only 80% of *S. zeamais* larvae emerged as adults after 23 days when emergence was completed. Temperature and r.h. conditions during the present study were not as high as recommended to be optimum for weevil reproduction. Maximum production is reported to be at temperatures of 27 to 30°C and 70% relative humidity (TDRI, 1984).

The number of emergence holes on each grain showed that females laid up to four eggs in a single maize grain. The percentage of kernels with one, two, three, and four weevil exit holes per kernel was 96.7, 2.99, 0.10, and 0.21%, respectively. This was in agreement with the findings of Adams (1976) who stated that the maize grain is sufficiently large to allow the development of two or more individuals of the weevil. Dobie (1974) also found a maximum of four holes per kernel of various maize varieties tested. In the present study the majority of kernels were with one weevil emergence hole.

Adult longevity was significantly greater in females than males (t_{28} = 3.67, $P<0.001$). Although, maximum longevity of greater than 118 days for male and 123 days for female weevils were recorded from individual observations, the average time for male and female survival were 66.91 and 98.13 days respectively (Table 2). The average time that adult weevils survived during this study was shorter than that indicated in many reports (e.g. TDRI (1984).

The information obtained may be useful in studies for control measures such as screening of resistant maize materials. However, further studies under controlled environments and more facilitated conditions are required in order to confirm the results.

The variability may be attributed to the use of different host varieties and insect strains as well as to differences in experimental conditions. The number of days required for the emergence of female weevils was relatively shorter (41.48) than male weevils (42.11 $P<0.001$) between weeks. The difference in the mean number of days required for adult emergence was not significant among eggs laid in the different weeks (Table 3).

Table 1. Parameters observed on the biology of the maize weevil (± standard error)

Observations	Male	Female
Duration of oviposition (days	-	90.40 ± 5.90
Interruption between successive oviposition (days)	-	3.19 ± 0.41
Effective oviposition days	-	49.13 ± 5.90
Days oviposition interrupted (mean total)	-	36.53 ± 3.95
Preoviposition period (days)	-	2.73 ± 0.88
Time between last oviposition and adult mortality (days)		5.00 ± 1.04
Adults produced per female	61.40 ± 11.34	60.40 ± 11.99
Development time (days)	42.11 ± 0.84	41.48 ± 0.84
Adult longevity (days)	66.91 ± 4.12	98.13 ± 5.75

Table 2. Mean (N = 15) number of weevils produced per female in different interval of days

Time interval (days)	Number of Weevils Emerged		Mean total
	Female	Male	
15-20	0.53	0.40	0.93
21-25	1.47	1.33	2.80
26-30	4.27	3.60	7.87
31-35	6.73	6.00	12.73
36-40	13.93	11.73	25.66
41-45	18.73	20.93	39.66
46-50	9.73	10.67	20.40
51-55	3.93	5.13	9.06
56-60	0.60	0.60	1.20
61-65	0.20	0.67	0.87
66-71	0.40	0.27	0.67
Mean	60.52	61.33	121.85

Table 3. Mean number of weevils produced\female\week and time needed for adult emergence

Week no.*	Number of weevils emerged (n = 15)			Emergence time (day)
	Female	Male	Mean	
1	5.40	7.26	12.67	44.14
2	4.20	3.73	7.93	46.00
3	2.27	2.20	4.47	42.61
4	3.00	3.20	6.20	42.51
5	2.27	2.87	5.13	44.76
6	2.13	2.60	4.73	47.35
7	4.73	4.53	9.27	43.64
8	4.53	4.27	8.80	42.77
9	3.20	3.27	6.47	42.09
10	3.80	2.80	6.60	42.06
11	3.27	4.13	7.40	44.50
12	2.87	4.27	7.13	40.18
13	5.33	5.13	1.47	39.70
14	7.73	5.60	13.33	35.70
15	5.80	5.47	11.27	35.81
Mean	4.04	4.09	8.12	42.25

* Weeks 1-3 were in June, 3-7 in July, 7-11 in August and 11-15 in September.

Table 4. Mean monthly temperature and relative humidity of the laboratory, 1989, BRC.

Month	Temperature (°C)			Relative humidity (%)		
	Min.	Max.	Mean	Min.	Max.	Mean
Jun.	21.36	25.41	23.39	55.91	63.63	59.77
Jul.	21.78	25.59	23.63	50.35	55.11	52.73
Aug.	22.14	26.56	24.35	57.15	62.15	59.65
Sept.	22.62	27.31	24.97	57.10	62.40	59.76
Oct.	22.83	27.99	25.41	50.08	55.92	53.00
Nov.	22.42	27.67	25.05	44.84	48.98	46.91
Dec.	22.24	25.31	24.03	49.08	55.15	52.12
Jan.	22.42	24.90	23.66	43.06	46.21	44.64
Feb.	23.16	26.28	24.72	40.52	46.87	43.70
Mar.	24.06	28.21	26.13	40.05	49.65	44.85
Apr.	24.37	28.27	26.32	33.07	49.33	43.20
May	24.00	28.20	26.10	45.80	58.70	52.30
Mean	22.78	26.85	24.82	48.50	55.34	51.89

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Effect of *Callosobruchus maculantus* Eggs' Odor Concentration Versus Waiting Time on Host Location by *Uscana lariophaga*

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Abstract

Callosobruchus maculantus is the most important pest of stored cow pea. As cow pea is grown by poor farmers, low input effective control measures of the pest are needed. Such methods include the use of indigenous natural enemies. Hence, the biology of *U. lariophaga* was studied at Wageningen Agricultural University. As part of the investigation effect of egg density in host location by U. lariophaga was studied in a tube diffusion olfactometer. The egg densities tested were 2, 8 and 64. The waiting time before the introduction of the wasp were 10 and 30 minutes.

The result obtained indicated that U.lariophaga, in the current set-up did not show an attraction behavior towards eggs. However. U.lariophaga significantly spent longer time in the treated half of the olfactometer indicating that the effect is an arrestment.

Neither the density of eggs or the waiting time for the installment of the odor gradient, significantly influenced the behavior of the wasp in the olfactometer.

Introduction

Callosobruchus maculatus (Fab.) is one of the most important bruchid species on cow pea. According to Caswell (1980 and 1981), *C. maculatus* causes more than 90% loss in stored cow pea in Nigeria.

As cow pea is grown by resource poor farmers who lack money, education and access to modern technology, control measures which can be exploited at this level should be designed. Such control measures include the use of indigenous natural enemies.

Different parasitoids of *C. maculatus* were recorded (Van Albeek, 1991) of which *Uscana lariophaga* (Steffan) was found to be the most efficient causing 50 and 33.5 percent parasitization under field and storage conditions, respectively (Lammers and Huis, 1989). *U. lariophaga* is a small egg parasitoid of *C. maculatus* and other bruchids.

Owing to the efficiency of *U. lariophaga* as biological control agent against *C. maculatus*, studies with respect to its biology are under way at the university of Wagenningen. One of the study areas was investigating the mechanisms involved in host searching behavior of *U. lariophaga*. This experiment was undertaken to determine the host searching behavior of *U. lariophaga* and the effect of the number of host eggs and the kind of chemicals involved in host searching behavior of *U. lariophaga* and whether these chemicals are volatile or not.

Materials and Methods

Rearing and Preparation of the Insects. Van Albeek (1991) and Kashoek (1991) described *U. lariophaga* and *C. maculatus*, respectively, and their techniques were followed to rear both insects.

Preparation of U. lariophaga. Daily at 5 p.m. from the experiment stock a set which started emerging was taken and blown off to get rid off the old wasps. Next morning, wasps were isolated from the blown sets and sexed under the microscope, based on their antennae. The females were kept for experiment and the males were discarded. These wasps were taken to the climate room for one oviposition experience. The wasps were given one oviposition experience on 0-16 hr. Old *C. maculatus* eggs laid on cow pea beans.

Preparation of C. maculatus. Egg Every day at 5 p.m. *C. maculatus* were sieved off and put in petri dish. Prior to the introduction of beetles into the petri dishes, glass marbles were put inside. The number of beetles and the number of marbles depended on egg density desired. For high density about 350 to 400 beetles and one marble were used in each petri dish. For low density eggs 3 to 5 marbles and 15 to 25 beetles were used. Next morning at about 10 a.m. marbles were retracted from the petri dish and put in another petri dish.

Based upon the number of eggs required on each marble, selections of marbles were made by counting the eggs under the microscope.

As it was difficult to obtain the exact number of eggs on marbles the range of numbers were used. The number of eggs programmed in the computer were 2, 8 and 64. But, the actual number of eggs used in the experiment was 2-3 for 2, 6-10 for 8 and 48-71 for 64. The experiment was designed in such a way that each egg density is observed for 10 minutes and 30 minutes waiting time. Thus, six treatments were tested.

Experimental Set-up. The test was conducted using a diffusion olfactometer, which was 10 cm long glass tube with open ends and a hole in the middle as described by Hoek (1993). A plastic capsule was fitted to a hole in the middle of the tube from the bottom, so that movement of *U. lariophaga* is up-ward towards light. *U. lariophaga* was introduced to the olfactomer through the plastic capsule. After introduction *U. lariophaga* was allowed five minutes to come out of the capsule into the olfactometer. If *U. lariophaga* did not come out of the capsule within five minutes, it was forced to do so by gentle pricking using finger.

An odor source consisting of fresh (0-16 h. old) C. maculatus eggs on marble(s) at one end was tested against a clean marble(s) as a control at the other end of the olfactometer. The ends were closed by plastic caps followed inward by a glass marble (with eggs), and subsequently with a very fine gauze, a physical barrier which block *U. lariophaga* from the eggs.

The position of odor source and the control was changed alternatively. To facilitate the evaluation of the parameters the tubes were equally divided into 6 sections. The two ends of the tube were named as right and left one. The position at which the plastic release capsule fitted to the olfactometer was named as center (Figure 1). After *U. lariophaga* has been released into the tube, observations were made for 15 minutes on the following parameters: arrival time in seconds, walking time in seconds and sitting time in seconds, number of wasps arrived and not arrived, and first choice. Bahaviours and time spent in each sections of the olfactometer were registered using a portable computer with the observer software (Noldus, 1991). The data were analyzed using Wilcoxon signed rank test, Mannwhitney U test and Chi-square test. The experiment was carried out in a climate room (30 $\pm$ 10c. 38 $\pm$ 3% r.h.). The experimental set-up was placed in a white tent on a white surface cartoon. The light intensity was about 1400 lux within the tent.

Results and Discussion

Total Time Spent. Results of total time (all behaviours included) spent by *U. lariophaga* in treated and untreated sections of the olfactometer are summarized in Table 1 and 2. U.lariophaga significantly spent more time in treated sections than the untreated sections of the olfactometer (Table 1). But, when this difference was analyzed for egg density and waiting time, it was found to be non-significant (Table 2). This indicate that the effect seen was not an attraction, but it is an arrestment. Attraction involves an oriented movement (taxis) towards a stimulus while arrestment is an increased residence time of an individual in a certain area after perception of a stimulus (Noldus, 1989).

The presence of eggs in one section of the olfactometer diminished the movement of *U. lariophaga* in control side where there is no eggs. The non-significance variation observed among the eggs density indicate that the minimum egg density (2 eggs) used is may be enough to elicit stimulus quite enough for arresting *U. lariophaga* within the treated section of the olfactometer. Meanwhile, the non-significance difference observed between the waiting times indicate that the substance involved in arrestment does not take more than 10 minutes to be released.

Walking Time. The dominant behavior that *U. lariophaga* exhibited in diffusion olfactometer is walking *U. lariophaga* significantly walked more time in treated sections of the olfactometer than the untreated sections (Table 3). The time spent in treated sections was not significantly different for egg density and waiting time (Table 4) which confirms the result obtained in total time.

U. lariophaga spent more than 60% of the observation period walking in different parts of the tube of which about 75% is in the treated side.

Sitting and flying time. Though *U. lariophaga* sometimes showed sitting and flying behaviors in diffusion olfactometer. However, it can be concluded that in current set-up waiting time about 69 per cent of the wasps made their first choice to the treated side.

In general, *U. lariophaga* significantly made their first choice to the treated side of the olfactometer than the untreated side.

Table 1. Mean total time spent by *U. lariophaga* in treated and untreated sections of the olfactometer, in relation to egg density and waiting time

Egg tmt	Time tmt	N	T1	C8	T12	C78	T123	C678	T1234	C5678
2	10	33	39(45)	27(50)Ns	178(180)	83(102)*	291(255)	156(167)	484(265)	414(266)Ns
2	30	33	62(126)	33(50)Ns	150(177)	129(163)Ns	275(254)	208(235)Ns	509(321)	391(321)Ns
8	10	32	78(131)	26(45) +	187(186)	93(104)*	301(252)	222(209)'	474*-275)	417(268)Ns
8	30	34	37(39)	32(51)Ns	145(134)	99(106)Ns	287(217)	166(153) +	564(235)	319(228)**
64	10	35	72(92)	21(49)*	231(223)	263(228)*	346(290)	321(269)	558(286)	341(286)*
64	30	32	95(148)	31(48) +	247(210)	108(123)*	372(267)	193(165)*	530(290)	369(290)Ns

Egg tmt = egg treatment in all tables
Time tmt = time treatment (waiting time) in all tables
Ns = not significant in all tables
+ = P < 0.1 in all tables
* = P < 0.05 in all tables
** = P < 0.01 in all tables
N = number of wasps tested or number of replications in all tables
O = number in the parenthesis refer to the standard deviations in all tables
1 = total observation time equals to 15 minutes or 900 seconds in all tables

Table 2. Effect of egg density (Kruskal-Wallis Test) and waiting time (Wilcoxon Matched-Pairs Signed-ranks Test) in total time spent by *U. lariophaga* in treated section of the olfactometer)

Egg tmt Ns	Time tmt Ns	N	T1	T12	T123	T1234
2	10	33	39(45)	178(180)	290(255)	484(265)
8	10	32	78(131)	187(186)	301(252)	474(275)
64	10	35	70(72)	231(224)	346(280)	558(286)
2	30	33	62(126)	150(177)	275(254)	509(321)
8	30	34	37(39)	145(134)	287(217)	564(235)
64	30	32	95(95)	247(210)	372(267)	530(290)

Arrival time. Arrival time of *U. lariophaga* at the odor source (T1) was not significant for egg density and waiting time. But, the trend looks that it needs shorter time for *U. lariophaga* at high egg density and long waiting time to arrive at the odor source. The sitting and flying behaviors of *U. lariophaga* can not be used to evaluate the treatments under investigation.

First Choice. About 63% of the tested wasps made their first choice to the treated side of the olfactometer (Table 5). The egg density-waiting time is significant at 8 eggs and 30 minutes waiting time and 64 eggs and 30 minutes waiting time.

At 8 egg density and 30 minutes waiting time about 77 per cent of the tested wasps made their first choice to treated side (Table 5).

Conclusion

Mean total time and walking time spent by U.lariophaga at the treated side of the olfactometer were higher than at the control side. In a number of cases, these differences are significant. It can be therefore concluded that egg odor results in an arrestment of *U. lariophaga* in a current set-up.

Mean arrival time at the treated end was not significantly different for different egg densities nor for different waiting times. Thus, no attraction of U.lariophaga to different odor concentration was demonstrated.

Table 3. Mean walking time spent by *U. lariophaga* in treated and untreated sections of the olfactometer in relation to egg density and waiting time (Wilcoxon-Matched-Pairs Signed-Ranks Test).

Egg tmt	Time tmt	N	T1	C8	T12	C78	T123	C678	T1234	C5678
2	10	33	39(46)	27(50)Ns	142(133)	82(102) +	226(183)	132(140)*	342(206)	227(188)*
2	30	33	50(104)	33(51)Ns	135(159)	129(165)Ns	214(206)	199(239)Ns	307(243)	266(278)^{Ns}
8	10	32	77(130)	25(46) +	185(186)	92(105)*	276(233)	188(164)Ns	398(258)	292(204)^{Ns}
8	30	34	37(39)	32(52)Ns	143(132)	99(107)Ns	257(197)	156(154) +	370(236)	237(181)
64	10	34	72(93)	21(49)*	219(221)	78(113)Ns	312(274)	148(172)*	430(271)	249(225)*
64	30	32	94(150)	31(49) +	228(211)	101(122)*	319(249)	158(152)**	412(275)	235(200)*

Table 4. Effect of egg density and waiting time (Kruskal-Wallis1-way anova) on time spent walking by U.lariophaga in olfactometer (Mann-Whitney U-Wilcoxon Sum W Test)

Egg tmt Ns	Time tmt Ns	N	T1	T12	T123	T1234
2	10	33	39(46)	142(133)	226(183)	342(206)
8	10	32	77(130)	185(186)	276(233)	393(258)
64	10	34	72(93)	219(221)	312(276)	430(271)
2	30	33	50(104)	135(159)	214(206)	307(243)
8	30	34	37(39)	143(133)	257(197)	370(236)
64	30	32	94(150)	228(210)	319(249)	412(275)

Table 5. Number and percentage of wasps making their first choice for the side of the tube in which host eggs were offered, and those choosing the control side.

Egg tmt	Time tmt	N	n_1	n_2	%n_2
2	10	33	13	20	61NS
2	30	33	12	21	64NS
8	10	32	17	15	50NS
8	30	34	8	26	77**
64	10	34	14	20	59ns
64	30	32	10	22	69*
TOTAL		198	74	124	63**

n_1 = number of wasps choosing control side
n_2 = number of wasps choosing treated side

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Sowing Date Against Stalk Borers, *Chilo partellus* (Swinhoe) and *Busseola fusca* (Fuller) on Sorghum in Central Ethiopia

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Abstract

Experiments on the effect of sowing dates on infestation and damage of the stalk borers, *Chilo partellus* (Swinhoe) and *Busseola fusca* (Fuller), on sorghum (var. Seredo) were carried out at Melkassa Research Center of the Institute of Agricultural Research (in 1992 & 1993) and at Zway research Center of the Awassa College of Agriculture (in 1993). Using four planting dates at 15 days interval replicated two times, infestation and damage found to be high in late sown (July 15) sorghum at both locations. At Zway infestation and damage appeared to increase progressively with delay in planting; infestation as high as 89.9% leaf damage and 64.4% chaffy head and the lowest yield, 86 Kg ha^{-1} was recorded from the last sowing as opposed to 14.6% leaf damage, 2.2% chaffy head and 2710 Kg ha^{-1} yield observed in the first sowing (June 1). Although the lowest yield per plot was recorded from the last sowing at Melkassa in both years, specific trend in infestation and damage as in Zway was not observed; low infestation and higher yield were recorded from the second (June 15) and third (July 1) plantings.

Introduction

Sorghum, *Sorghum bicolor* (L) Moench, is one of the major food crops grown by millions of people in Ethiopia. It grows in a wide range of environment although it is dominant in low land regions where drought and poor harvest are common occurrences (Birhane, 1977). One of the major factors attributed to poor harvest in this area is the problem of insect pests. It has been observed, (Harris 1962) that any factor hindering normal development of a crop tends to intensify pest damage. To date about 38 insect pests are recorded attacking sorghum in Ethiopia (Adhanom and Abraham 1986). Of these the stalk borers, *C. partellus* and *B. fusca*, are the most important ones. It has been reported that effective control of *C. partellus* can be achieved by applying cyhalothrin at 16 g a.i./ha (IAR, 1987). However, Ethiopian farmers like farmers of many developing countries are not users of pesticide for pest control especially in low cash value crops. Expensiveness and unavailability of the pesticides and the application equipment are the major reasons. The protection afforded by the stem of the crop to the developing and damaging stage of the insects also limits the use of pesticides in farmers field as chemicals are applied after the damage symptoms are observed. Cultural control of insect pests defined as the tactical use of regular farm practices to delay or reduce pest attack (Seshu Reddy, 1985) are good pest management options for resource poor farmers. This experiment was therefore conducted to identify optimum planting date that could minimize stalk borers damage in sorghum for use in the integrated management of the insects.

Materials and Methods

The experiment was carried out at Melkassa Research Center of the Institute of Agricultural Research (IAR) in 1992 and 1993 and at Zway Research Center of Awassa College of Agriculture (ACA) in 1993 in a randomized complete block design replicated two times.

The variety, seredo, was planted in a 12 rows of 10 m long each plot, 75 cm between rows and 15 cm between plants, at 15 days interval between June 1 and July 15. Data on the number of plants showing leaf feeding symptoms were taken fortnightly after the emergence of the crop from the central two rows of each plot. The population of the insect was determined by uprooting 10 plants from the border 10 rows of each plot and counting the larvae and pupae of the insects by dissecting the stalks every 15 days after the crop emerged (DAE). At harvest peduncle damaged plants, stalk borer chaffy head, harvestable head and yield were recorded from the central two rows of each plot.

Results and Discussion

The composition of *C. partellus* and *B. fusca* was 6.8 and 93.2% at Ziway; and 96.4 and 3.6 in 1992 and 98.2 and 1.8% in 1993 at Melkassa. Infestation and damage by the pests in different sowing dates were different (Table 1, 2, and 3); higher incidence of the insect and significant differences between sowing dates were observed at Zway in 1993 (Table 1). A sharp decline in yield with delay in sowing in response to progressive increase in percent leaf damage and stalk borer chaffy head was observed (Table 1). The highest population of the insect, 47.6 per 10 plants, was also recorded from the last planting, July 15 (Table 1).

The correlation between yield and damage was negative and highly significant: yield with leaf damage at 60 DAE ($r = -0.972$, $P = 0.000$), with peduncle damage ($r = 0.770$, $P = 0.021$), and with stalk borer chaffy head ($r = -0.961$ and $P = 0.000$). Leaf damage at 15 and 30 DAE did not correlate with yield. It was ($r = -0.027$, $P = 0.949$) at 15 DAE and ($r = 0.052$, $P = 0.902$) at 30 DAE. The correlation between yield and number of insects was also negative and significant ($r = -0.972$, $P = 0.014$). At Melkassa infestation and damage by the pests were not severe as in Ziway as can be observed by low percentage of leaf damage and chaffy head in both years although the severity was higher in 1993 than in 1992 (Table 2 & 3). Lower number of stalk borers and higher yield were observed from the third and second plantings in 1992 and 1993 respectively. However, higher number of stalk borers and lower yield were recorded from the first (June 1) and last (July 15) sown plots in both years (Table 2 & 3). Although the lowest yield was recorded from the last sowing in both years, significantly low yield from the last sowing was observed in 1993 due to higher number of insects and increasing infestation (Table 3). Data on infestation both during the growing period and at harvest did not correlate significantly with yield. For example, the correlation between leaf damage at 60 DAE, insect population and chaffy head with yield was ($r = -0.314$, $P = 0.444$), ($r = -0.557$, $P = 0.114$) and ($r = 0.119$, $P = 0.778$) respectively in 1992 and ($r = -0.687$, $P = 0.054$), ($r = -0.470$, $P = 0.234$) and ($r = -0.265$, $P = 0.523$) in 1993.

This study indicated that time of sowing and incidence of stalk borers in sorghum are location specific. A sharp increase in infestation and hence a decrease in yield with delay in planting at Zway indicated the importance of early planting as cultural control of stalk borers in sorghum. On the other hand, neither early (June 1) nor late (July 15) planting resulted least infestation at Melkassa. As pointed out earlier higher number of stalk borers and lower yield were observed from these planting dates. In Malawi, Mchowa (1990) studied the effect of four sowing dates on the incidence of *B. fusca* in two varieties of sorghum (Serena and ZSV1) and found that the incidence of this pest was highest in the first and fourth sowings of serena but highest on the second and third sowings of SZV1. His observation in Serena maintains similar results with our observation at Melkassa.

The relative advantage of early sowing over late sowing of different crops to minimize pest damage has been reported by several workers. In Ethiopia Assefa *et al.* (1989) observed that infestation of late sown maize attacked by second generation *B. fusca* was higher (22 - 100%) than early sown maize attacked by the first generation (0 - 22%). Swaine (1957) in Tanzania and Abu (1986) have also reported the advantage of early planting to minimize stalk borer damage in sorghum. The effect of different sowing dates on pest incidence in any crop is the result of different factors such as climate, variety, cropping system pest species etc. Location specific experiments is therefore required to use sowing date as a component of stalk borers management.

Table 1. Infestation and damage of sorghum (var. seredo) sown on different dates by the sorghum stalk borers, *C. partellus* and *B. fusca* at Zway, 1993.

Sowing dates	% leaf damage	No. of larvae/10 plants	% chaffy head	Yield (Kg/ha)
June 1	14.6	17.9	2.2	2710
June 15	58.2	37.3	15.9	1734
July 1	85.8	35.3	44.9	461
July 15	89.9	47.6	64.6	86
CV (%)	13.9	14.7	32.3	27.3
LSD (0.05)	27.5	16.2	32.8	1086

Table 2. Infestation and damage of sorghum (var. seredo) sown on different dates by the sorghum stalk borers, *C. partellus* and *B. fusca* at Melkassa, 1992.

Sowing dates	% leaf damage 60 DAE	Number larvae/ 10 plants	% chaffy head	% peduncle damage	Yield (kg/ha)
June 1	25.8	20.3	2.4	41.3	2866
June 15	27.1	16.1	0.0	28.7	2859
July 1	11.5	11.9	0.0	31.4	3634
July 15	9.4	22.0	0.0	29.1	2417
CV (%)	46.9	7.38	35.4	32.6	31.8
LSD (0.05)	27.5	5.7	0.7	NS	NS

Table 3. Infestation and damage of sorghum (var. seredo) sown on different dates by the sorghum stalk borers, *C. partellus* and *B. fusca* at Melkassa, 1993.

Sowing dates	% leaf damage 60 DAE	Number of larvae/ 10 plants	% chaffy head	% peduncle damage	Yield (kg/ha)
June 1	56.7	43.3	5.6	72.2	3083
June 15	28.8	23.6	5.7	58.6	3841
July 1	25.8	30.9	2.7	73.1	3764
July 15	49.7	35.6	6.7	62.1	2026
CV (%)	27.5	12.5	41.8	3.9	9.7
LSD (0.05)	35.3	13.3	NS	8.3	981

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Performance of Maize/Bean Intercropping Systems Under Low and Medium Rainfall Situations: Insect Pest Incidence

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Abstract

Maize/bean intercropping experiments were conducted at Melkassa and Awassa during 1992 cropping season. Two early bean varieties with different growth habits were planted simulataneously with maize and relay planted one month after maize planting in different planting patterns in a randomized complete block design. The objective of the experiment was, to evaluate insect pest incidence in maize and bean intercrops subjected to different planting patterns and planting schedules of bean varieties at Melkassa and Awassa.

The effect of bean varieties on infestation of pests either in sole culture or intercropped treatments were inconsistent at both locations. Statistically significant difference in stalk borer incidence was observed between sole culture and other treatments, but not between bean varieties and planting patterns at both locations. Significant difference in cob worms incidence was observed between and within each factor at Melkassa but not at Awassa. The results reveal that higher infestation of beanfly and pod borer were observed from row patterns as compared to broadcast patterns and from relay intercrops compared to simultaneous intercrops at both locations. In general, planting beans simultaneously with maize in intercropping systems could serve as a means of reducing yield losses due to insect pests, in addition to improving the productivity and yield stability of the component crops at Melkassa and Awassa.

Introduction

Intercropping is widely practiced by subsistence farmers in the tropics for several purposes, one of which is reductions in insect pest numbers, and hence reductions in crop damage and yield losses. Cropping systems can affect population dynamics of insect pests by interfering with the colonization of the crop, the development of pest populations, dispersal of the pest, or by influencing the abundance of natural enemies (Altieri, 1984).

Intensive cropping systems may hamper colonization of crops by insects through their influence on the visual and olfactory stimuli of the pest, and through the action of some crops as diversionary host plants. Visual cues are important in the colonization of crops by insects. For example, a solid green background in a diverse environment is suggested to be less attractive to some pests than is a foliage-bare ground contrast in a monoculture. This is perhaps open reason for low bean fly counts in weedy haricot bean plots, compared with weed-free bean monoculture reported from Awassa (Tsedeke Abate, 1990). In some instances, one crop may become camouflaged by another from flying insects. Orientation to host plants in insects is known to involve olfactory mechanisms; presence of several plant species may disturb this mechanism. Moreover, one crop in intercropped fields may represent a physical barrier to the successful colonization of another by insects (Hasse and Litsinger, 1981).

Epidemics are favored by morphologically and genetically uniform crops grown on large are of land, where pests find all their food, shelter and oviposition requirements within the crop. In contrast, a combination of genetically different crops grown together in the same field does not provide the uniform substrate needed by pests to multiply rapidly and acquire epidemic proportions. The incidence of pests therefore, may be reduced in intercrop, relative to sole crop, but this is not invariably the case. Much depends on factors such as host range of the insect species concerned and the relative sowing times and spatial arrangements of the associated crops. Certain pests colonize one particular crop in a given ecosystem, which then serves as a diversionary host, protecting other more susceptible or economically valuable crop from severe damage. On the other hand, can move from one host to another when one of the host plants matures. It is critical, therefore, to select the correct plant diversity for a given micro-climatic, biotic and intercrop situation; a specific diversity in the same system can be beneficial in one region but harmful in another (Bhatnagar and Davis, 1981).

Since scientific information on the relative benefits of intercropping is very limited in Ethiopia, experiments were conducted at Nazret and Awassa, to compare maize or bean sole crops with intercrops and to identify temporal and spatial patterns that can increase yields on-sustainable basis and that can minimize the incidence of insect pests.

Materials and Methods

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications at Melkassa and Awassa. An early maize variety, Katumani composite and two bean varieties with different growth habits, Awash-1 (erect type) and M-142 (semi-prostrate) were planted simultaneously with maize and relay planted one month after maize planting. Sole beans were sown at recommended planting dates, early and late June for Awassa and Melkassa, respectively. The planting patterns used were sole maize, sole beans, 2 rows of maize/1 row of beans, maize/bean mixed in the same row, maize in rows/bean broadcast and maize.bean both broadcast. Hence, 19 treatment combinations were maintained from 2 bean varieties, 2 times of planting them, 4 intercrop arrangements and 3 sole crop treatments (1 for maize and 2 for beans). The total plant population maintained was 100% of sole maize and 50% of sole beans in all intercropped patterns, but 100% of sole crop was used in each of sole cultures of maize and beans.

Stalk borer (*Busseola fusca* (Fuller) and *Chilo partellus* (Swinhoe), cob worms (*Eublemma gayneri* (Roths.), *Busseola fusca* (Fuller) and *Heliothis armigera* (Hubner) incidence on maize were assessed at harvest from 25 plants selected randomly from each plot. Beanfly (*Ophiomyia* sp.) incidence was assessed at seedling stage (at thinning) from 1 m^2 and at harvest from 25 plants selected randomly from each plot; there after add up as reported in this paper. Moreover, pod borer (*Heliothis armigera* (Hunber), incidence was assessed at harvest from 25 plants selected randomly from each plot.

The observations made were computed to percentages from respective sampled plants and statistically analyzed using MSTAT-C computer program. Treatment effects were analyzed using all 17 and 18 treatment combinations for maize and bean components (Experimental model number 7), respectively. Interaction effects were analyzed considering three factor factorial analysis (2 bean varieties x 2 planting schedules x 4 planting patterns) with a total of 16 treatments by dropping out the sole crop treatments (Experimental model number 10).

Results and Discussion

Significantly higher incidence of stalk borer and cob worms was observed from sole maize compared to intercropped treatments (Table 1). Higher stalk borer incidence occurred in maize planted in maize/bean mixed in the same row arrangement at both locations, while inconsistent trend was observed in cob worms incidence across locations. No significant difference in varietal effects was observed between intercrops with Awash-1 and M-142 for both pests at Awassa, while there was significant effect for cob worms incidence at Melkassa. Moreover, planting schedule of beans significantly affected the incidence of stalk borer and cob worms in maize plants at Melkassa, but not at Awassa. Higher stalk borer incidence occurred in simultaneously planted maize intercrops, whereas higher cob worms incidence occurred in maize relay cropped with beans at both locations.

Lower incidence obtained from intercropped treatments could e due to the structural and vegetations diversity resulting from the addition of crop plants in space. On top of the difference in climatic conditions across location, the availability of alternate hosts at Awassa might have aggravated the incidence of stalk borer and cob worms. Adhanom Negasi and Abraham Tadesse (1985) reported that the nature of distribution of some of these alternate host plants makes them potentially important reservoir for the insects in Ethiopia and most of these hosts grow along the shores of the rift valley lakes. Moreover, the higher incidence of cob worms might have depended on factors such as the host range of the insect species concerned. Some insect pests can attack several plant species and can move from one host to another when one of the host plants matures. This was the case in African boll worm where it shifted from matured beans to maize ears and contributed to higher cob damage under Awassa conditions while it was less at Melkassa, because both crops mature relatively at the same time.

Statistically significant difference was observed between intercropped treatments and sole cultures for bean fly and pod borer incidence at Melkassa; however, no significant effect was observed between sole cultures of both bean varieties (Table 2). At Awassa, no significant difference was observe between bean varieties either in sole culture or in intercropped beans in bean fly incidence. On the other hand, significant difference in pod borer incidence occurred between bean varieties either in sole culture or in intercrops. M-

142 suffered more by pod borer under sole culture than intercrops, whereas the reverse was true for Awash-1 under Awassa condition. Significantly less incidence of bean fly and pod borer occurred in beans planted simultaneously with maize compared to beans relay planted one month after maize planting at both locations. Intercrop arrangements affected the incidence of bean fly and pod borer; where higher incidence of both bean varieties occurred in row arrangements at both locations.

Table 1. Effect of bean varieties, planting pattern and planting schedule of beans on maize insect pest incidence at Melkassa and Awassa.

	Percentage of			
	Stalk borer		Cob worms	
	Melka	Awassa	Melka	Awassa
Planting Pattern:				
Sole Maize	02.0	85.0	8.2	92.2
2 Maize/1 Bean intercrop	11.0	73.5	3.5	69.0
Both mixed in same row	13.5	81.0	2.8	70.4
Maize row/bean broadcast	11.5	78.0	2.3	71.1
Maize/bean both broadcast	11.5	74.5	3.4	72.5
Bean Varieties:				
Intercrop/Awash-1	12.0	75.0	3.4	72.2
Intercrops/M-142	12.0	79.0	2.4	69.2
Planting Schedule:				
Simultaneous intercrops	15.5	80.0	2.5	67.6
Relay intercrops	9.0	73.5	3.3	73.9
CV(%)	8.95	6.24	11.73	6.08
LSD (0.05) Between Treatments	2.45	8.00	0.62	7.28
Planting Pattern x P. Schedule	1.22	NS	0.43	5.26
Planting Pattern x B. Varieties	1.22	5.80	0.43	5.26
Planting Schedule x B. Varieties	NS	NS	0.30	3.72
P. Pattern x B. Var. x P. Sch.	NS	NS	0.60	7.44

Table 2. Effect of bean varieties, planting pattern and planting schedule of beans on maize insect pest incidence at Melkassa and Awassa.

	Percentage of			
	Beanfly		Pod borer	
	Melka	Awassa	Melka	Awassa
Planting Pattern:				
Sole Awash-1	4.0	3.7	30.8	12.4
Sole M-142	4.7	3.3	31.3	36.6
2 Maize/1 Bean intercrop	12.6	17.2	11.5	18.0
Both mixed in same row	12.5	15.5	11.8	21.9
Maize row/Bean broadcast	9.4	11.4	10.7	14.5
Maize/Bean both broadcast	8.3	10.0	10.5	14.0
Bean Varieties:				
Intercrop Awash-1	12.2	13.3	8.7	21.9
Intercrops/M-142	9.2	13.6	13.5	12.3
Planting Schedule:				
Simultaneous intercrops	3.0	2.3	4.2	2.2
Relay intercrops	18.4	24.6	18.1	32.0
CV(%)	8.61	8.19	8.78	13.52
LSD (0.05) Between Treatments	1.50	1.75	1.70	4.22
Planting Pattern x P. Schedule	1.08	1.30	1.15	3.09
Planting Pattern x B. Varieties	1.08	1.30	1.15	3.09
Planting Schedule x B.Varieties	0.77	NS	0.82	2.18
P. Pattern x B. Var. x P. Sch.	1.53	NS	1.63	4.36

Pods of Awash-1 were significantly damaged compared to pods of M-142 either in sole culture or intercropped at Awassa. However, it was reverse at Melkassa. This result is in agreement with the findings of Amare Belay (1992) that the intensity of bean pests infestation differ significantly among bean varieties under different climatic situations. Beans planted simultaneously with maize were damage less by bean fly and pod borer compared to relay planted beans at both locations. This might be attributed to either the early planted beans resist the infestation of pests or escaped from the outbreak of the pests compared to relay planted ones. In line with this findings Tsedeke *et al* (1985) reported that infestation on bean fly and pod borer increased with delay in bean planting. Moreover, the higher incidence in row pattern might be attributed to the efficient physical barrier of maize plants in broadcast patterns to movement of bean fly and African boll worm.

Increase in total population resulting from companion crops and because of the early presence of the beans in simultaneous intercrop might have presented some physical barrier to movement of the beanfly and African boll worm reducing their incidence. Consequently higher yields of beans were obtained from beans planted simultaneously with maize than relayed at both locations (Nigussie Tesfamichael and Reddy, 1995). These results agree with the farmers' objective that planting both crops simultaneously safeguard against beanfly and pod borer attack (Amare, 1992).

Intercropping makes excellent biological system for reduction of pest incidence. The results indicated that maize/bean intercrops significantly reduced the incidence of stalk borer, maize cob worms, beanfly and pod borer at both locations. Planting beans in rows simultaneously with maize gave higher component yield of both crops at both locations (Nigussie Tesfamichael and Reddy, 1995). It can, therefore, be recommended that planting both bean varieties simultaneously with maize in 2 rows maize/1 row bean reasonably reduced insect pest incidence and increased total production per unit of land per year.

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The Influence of Sowing Date on the Damage by Tef Fly (*Delia arambourgi* (Seguy): Anthomyiidae) on Tef at Anno

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Abstract

Tef, *Eragrostis tef* (Zucc.) Trottor, is an important cereal crop in Ethiopia. Tef fly, Delia arambourgi (Seguy), attacks tef in many tef growing areas of the country. Sowing date experiment was conducted for three years (1986/87-1990/91) in Bako area in order to determine the best time for sowing tef that gives maximum yield and minimum infestation by the pest. Shoots with dead heart symptoms were counted at random from each plot from early seedling stage till harvest. The results indicated that second to third week of July (July 12 to 22) is the best time to plant tef in Bako. Under favorable conditions tef can tolerate infestation by tef fly to get high yield, although the fly infestation is also high on the crop plantation on these days. This, however, indicates that the local tef cultivar tolerates the infestation by the tef fly during favorable growing condition for the crop that include adequate rainfall and fertilizer application.

Introduction

Tef, *Eragrostis tef* (Zucc.) Trottor, is one of the most important cereal crops in Ethiopia and it is the most preferred national diet. In the Bako area tef serves a dual purpose: as cash crop and supplementing maize for injera. It is potentially a low-yielding cereal, and this low yield has further been lowered by several biotic and abiotic constraints. Damage caused by insect pests is one of the most important factors contributing to the reduction in yield of the crop.

Tef fly, also called barley fly (*Delia arambourgi* (Seguy)) is an important pest of barley; and a minor pest of maize, wheat bulrush millet and some other grasses in Africa (Hill, 1983). Since its record in Ethiopia, the fly has become increasingly important pest of barley and tef in some areas (Crowe et al., 1977; Tadesse. 1979; IAR, 1985). Adugna (1985) observed that barley fly prefers barley and tef more than wheat and oat. The larva feeds on the stem of the central shoot causing a typical shoot borer "dead heart" symptoms. The growing larva in the main stem was observed to cause blind heads shortly before harvest. Crop loss in barley due to this pest can be as high as 38% and the attack could be devastating depending on the season (Betru, 1975). A single maggot can destroy 3-4 seedlings (shoots) (Hill, 1983) and if accompanied by drought, it will result in complete loss of the crop.

In some tef growing areas around Bako (Wamma and Anno) heavy infestations are common on tef. During off-seasons, dead heart symptoms appear on wild grasses such as Setaria and Digitaria. Infestations appear to be more pronounced in late-sown fields of tef than fields planted earlier, although this may not be the case always. On the other hand, IAR (1972) reported that barley planted in June is more severely attacked than that planted in July. Although, farmers in Bako area plant tef in July and early August, there is no experimentally determined time for planting tef in the area (Legesse et al., 1987). The objective of this study was to determine the best time for sowing tef in Bako area that results in minimum damage by tef fly and maximum grain yield.

Materials and Methods

The experiment was conducted for three years (1986/87-1990/91) on sandy clay loam soils at Anno, 15 km west of the Bako Research Center, where fly infestation was frequently observed. Sowing date treatments in the first year were July 3, 15 and July 30; August 14 and August 29; and September 13. In the other years the treatments were June 22; July 2, 12 and July 22; August 1 and August 11. The experiment was laid out in a randomized complete block design with four replications. The plot size was 5 m x 8 m. A local tef variety was hand broadcast at the rate of 30 kg per hectare. Fertilizer was applied at the rate of 40/40 N/P_2O_5 per hectare during sowing. Weeding was done twice in each growing season. The parameters considered include number of shoots with dead heart symptoms and grain yield. Dead heart count was made by taking five quadrant counts from each plot at random starting from early seedling stage (a month after emergence) up to harvest. These heart counts were transformed into square-root and all data were subjected to statistical analysis combined over the years.

Results and Discussion

Significant differences were observed between sowing date treatments in the 1986/87 crop season (Table 1). The lowest fly damage and grain yield was recorded from plots sown on August 14. The reason for the low yield was insufficient and poor distribution of rainfall. Tef sown on August 29 and September 13 failed to generate data because of lack of rainfall. July 3, 15 and 30 sowing dates did not differ from each other in fly damage although the difference in grain yield was significant. Maximum grain yield was obtained from plots planted on July 15, when fly damage was significantly high.

Data were not collected from the 1987/88 and 1989/90 trials because of damage from animal, in the former, and drought, in the latter seasons. The combined analysis of variance of 1988/90 and 1990/91 seasons showed significant differences in fly damage and grain yield (Table 2).

Significantly high fly-damaged plants were recorded from July 22 followed by July 2, July 12 and August 1 sowings. The earliest and the latest sowings showed significantly low level of damage. Significantly high yield records were obtained from July 12 and July 22 sowings.

Table 1. Effect of sowing date on tef fly damage and grain yield of tef in the Bako area (1986/87)

Sowing dates	Damage count* (No./1.25 m^2)	Grain yield (kg/ha)
July 03	15.00	930
July 15	14.05	1005
July 30	11.45	960
August 14	7.70	360
August 29	-	-
September 13	-	-
S.E. (±)	(1.28)	0.16
LSD 5%	(4.11)	0.51
1%	(5.90)	0.74
CV (%)	(21.30)	9.85

* = average of 15 quadrants per plot,
Values in parenthesis are square - root transformed values

Grain yields of the first two (June 22 and July 2) and the last two (August 1 and August 11) sowing date treatments were statistically similar in the combined analysis. However, analysis of individual seasons showed that June 22 and July 2 sowings in 1988/89 (Table 3), and August 1 and 11 sowings in 1990/91 (Table 4) suffered significant yield losses because of low moisture at sowing and at early plant establishment periods.

According to this study, second to third week of July is the best time to plant tef. This agrees with the general recommendation given for planting tef on andosols (Seyfu, 1993). However, planting may be possible from as early as the first week of July (July) to as late as the first week of August (August 1) if there is reliable moisture during planting and subsequently. Seyfu (1993) reported that early planting (beginning of July) on andosols usually induces lodging and disease incidence. However, with varieties resistant to lodging and disease, it would be possible to increase yield by using earlier sowing dates.

High yield records were obtained from sowing dates showing high fly infestation. This may suggest that the local tef variety is tolerant to attack by tef fly. It was reported (IAR 1983) that in seasons of adequate and well distributed rainfall heavy attacks by tef fly maggots can be sustained by the tef crop. According to another report (IAR, 1972), when rainfall is adequate barley would be able to recover from attack by barley fly and produce the same yield as that which escaped attack. Moreover, fertilizer application and high seed rate were found to reduce crop loss due to barley fly damage in barley.

The correlation between grain yield and number of damaged plants was not significant (r = 0.42). Lack of relationship between termite damage and yield reduction has been reported in maize (Abraham and Adane, unpublished). According to Kumar (1984), even when the damage done to a crop appears heavy to the naked eye, the real loss of yield may be too small to necessitate control measure. However, loss assessment studies should be carried out in order to confirm the results of this experiment. Furthermore, since there are many shoot fly species attacking cereal crops in Ethiopia, whether one or several shoot flies are involved requires further study.

Table 2. Effect of sowing date on fly damage and yield of tef in the Bako area (1988/89-1990/91 average)

Sowing dates	Damage count* (No./1.25 m2)	Grain yield (kg/ha)
July 22	10.14 c	446.65 c
July 02	12.78 b	541.16 bc
July 12	12.32 b	669.53 ab
August 22	15.08 a	755.50 a
August 01	12.88 b	587.67 bc
August 11	10.07 c	447.00
S.E. (±)	(1.28)	50.74
CV (%)	(6.81)	25.00

* = average of 15 quadrants per plot,
Values in parenthesis are square - root transformed values

Table 3. Effect of sowing date on tef fly damage and grain yield of tef in the Bako area (1988/89 average)

Sowing dates	Dead heart (No/1.25 m2)	Grain yield (kg/ha)
June 22	11.63 c	117.68 c
July 02	12.80 bc	192.33 c
July 12	11.60 c	541.56 ab
July 22	16.63 a	664.12 b
August 01	15.00 ab	1015.96 a
August 11	10.75 c	763.99 b
S.E. (±)	(0.11)	70.55
CV (%)	(6.18)	25.69

Values in parenthesis are square - root transformed values

Table 4. Effect of sowing date on tef fly damage and grain yield of tef in the Bako area (1988/89 average)

Sowing dates	Dead heart (No./1.25 m^2)	Grain yield (kg/ha)
June 22	8.64 b	775.63 a
July 02	12.75 bc	890.00 a
July 12	13.04 a	797.50 a
August 22	13.54 a	846.88 a
August 01	10.75 ab	152.50 b
August 11	9.39 c	109.38 b
S.E. ($\pm$)	(0.92)	74.22
CV (%)	(10.30)	24.94

Values in parenthesis are square - root transformed values

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Response of Some Maize Varieties to Angoumois Grain Moth, *Sitotroga cerealella* (Olivier)

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Abstract

Maize is an important crop grown in Ethiopia. It is first in total production and yield per hectare. A farmers in Ethiopia produce on an average one to three tones of maize grain per season. The grain is stored for 6-9 months during which time heavy losses are encountered due to attack by *Sitotroga cerealella* and other stored grain pests. Different maize varieties respond differently to the attack of stored maize grain insect pests. Hence, varieties were screened against *S. cerealella* in free choice and no choice tests. Both tests were carried out in completely randomized design in three replications. The parameters used were number of F1 moths, percent kernel damage, length of developmental period, index of susceptibility and per cent weight loss.

Among the varieties tested UCB, H-8151 and H-501 in free choice test, and H-8151 and H-501 in no-choice test were found to be resistant. Both antixenosis and antibiosis type of resistance were observed in the resistant varieties. Number of emerged F1 moths, percent kernel damage and percent weight loss were found to be important parameters in screening maize varieties against *S.cerealella*.

Introduction

Maize, *Zea mays* (L.), is extremely an important crop grown in Ethiopia. It is first in total production and yield per hectare when compared to other cereals like sorghum, wheat, tef and barley (Benti et al, 1992). According to the survey made in Southern Ethiopia a farmer on an average produces one to three tones per season. However, farmers do not consume or sell this much grain but they normally store it for 6-9 months as an insurance against food shortage, to look for better market price and or to use it as a seed source.

Maize is heavily damaged in the store by various insect pests. Angoumois grain moth, *Sitotroga cerealella* (Olivier), is one of the destructive insect pests of stored maize grain in Ethiopia.

Maize varieties vary in susceptibility and attractiveness to *S. cerealella* owing to their chemical content and relative hardness of the kernels (Singh and Pandy, 1974). While a large number of new maize varieties have been bred for yield, adaptation to length of growing season, plant height, and resistance to several insect pests and pathogens of the growing plant, less attention has been paid to resistance to stored grain insects. The use of resistant varieties is important where farmers have a limited access to insecticides or equipment. It is also one of the most appropriate ways of avoiding or reducing problems connected with insecticide residues and the increasing array of insecticide resistant strains of insects (Painte, 1965).

In Ethiopia a number of maize varieties are under production. Therefore, this paper presents the response of the tested varieties to *S.cerealella*.

Materials and Methods

Twenty maize varieties were collected from Ministry of State Farm, Institute of Agricultural Research, Ethiopian Seed Enterprise, Awasa College of Agriculture and Alemaya University of Agriculture. These varieties were tested under laboratory condition in 1992 and 1993.

The varieties were A-511, Gutto Lmsc5, Kcc, pool-9A, UCB, Ev-1, Katumani, E.A.H.75, Abo Bako, Bako composite, Gutto, Birkata, KCB, Alamura early, Beletech, H-501, H-8151, H-625, K.synth.II and pop.43, and these were disinfested in deep freeze at -16°C for one month. After one month holed kernels were separated from sound kernels and the sound kernels were stored in 20 cm (diameter) X 30 cm rearing cage in the laboratory where the experiment was conducted. Grain conditioning for moisture was exercised for three weeks by either adding water to the kernels or thinly spreading the kernels on the laboratory table until 12-13.5% moisture was maintained.

Culture of *S.cerealella* was established by putting 250 moths in each of 5 rearing cages containing 2 kg of disinfested maize kernels. The F2 moths (0 to 7 hr) of this insect culture were used in free choice and no-choice tests.

Free choice test. Varieties were arranged in a circular arena in a cafeteria style. The moths were released from the center of the arena in the ratio of 10 moths to 400 kernels. The whole experimental set up was covered by muslin cloth. The experimental design was completely randomized design in three replications. Hundred kernels of each variety was used per replication. Nineteen days after release of the moths, kernels of each replication were placed in perforated plastic bag. These were kept in the laboratory at 27°c + 1°c and 70% R.H. until the end of the experiment.

Observation was made daily where emerged moths were counted and removed. This procedure continued until emergence of F1 moths ceased.

The parameters used to evaluate the varieties were number of F1 moths emerged, percent kernel damage, length of developmental period and index of susceptibility. Index of susceptibility was calculated using Dobie's (1974) formula which is enumerated as:

$$\text{Index of susceptibility} = \frac{\log_e N \times 100}{T}$$

where:

$\log_e$ = Napierian logarithms

N = F1 progeny

T = average developmental period

No choice test. The test was carried out once in 1993 after conducting free choice test twice in 1992 and 1993. In this test 10 relatively resistant, two susceptible and one standard variety were used. These varieties were H-8151, H-501, pool-9A, Gutto, UCB, H-625, k.synth.II, Bako comp., A-511, Katumani, KCB, Birkata and Alamura. The experiment was designed in completely randomized design replicated three times. In this test 100 kernels of each variety per replication were put in perforated plastic bag. Six newly emerged un-sexed moths were released to each plastic bag. Nineteen days after release, the adults were removed. The number of emerged F1 moths were daily counted and removed. Number and weight of damaged kernels were recorded when emergence of F1 moths ceased.

Percent weight loss was calculated by count and weigh method (Anon, 1969) using the following formula:

$$(\%)\ \text{weight loss} = \frac{[UND-(DNu)] \times 100}{U(Nd + Nu)}$$

Where,

U = weight of undamaged grains

Nu = number of undamaged grains

D = weight of damaged grains

Nd = number of damaged grains

Grain conditioning, disinfestation and other aspects were similar to that of free choice test.

Results and Discussion

Wide variation was observed among the varieties with respect to mean number of F1 moths, mean percent kernel damage and percent weight loss. In free choice test UCB, H-8151, and H-501 were found to be resistant (Table 1 & 2). However, in no choice test UCB become less resistant (Table 3). This may be explained in terms of resistance mechanism. Kogan and Ortman (1978) (quoted by CIMMYT, 1989) described two resistance modalities in stored products: antibiosis and antixenosis (non preference). The type of resistance mechanism exhibited by UCB was thus, antixenosis. In antixenosis type of resistance, resistance may break in the absence of preferred host. In no choice experiment since each variety received moths individually there was no choice for hosts. Thus, varieties which proved to be resistant in both free choice and no choice test are said to possess antibiosis type of resistance or both. In the current experiment H-8151 and H-501 seemed to possess such type of resistance modality. The parameters used to identify resistant varieties against *S. cereallela* proved to be useful.

Table 1. Response of maize varieties to S. cerealella in free choice test, 1992.

Variety	Mean F1 moths	Mean percent kernel damage	Mean develop-ment period	Index of susc.
A-511	4.66a-e	19.33a-c	48b	2.33
Gutto-Lmsc5	18.00ef	31.33bc	46b	9.00
Kcc	7.34b-f	27.33a-c	53ab	3.67
Pool-9A	7.34b-f	14.00a-c	56ab	3.67
UCB	0.66a	3.00a	53ab	2.00
EV-1	6.66b-f	26.67bc	56ab	3.33
Katumani	20.00ef	36.67c	55ab	7.00
E.A.H.75	7.34b-f	26.67bc	46b	3.67
Aba-Bako	16.00d-f	20.00a-c	49ab	8.00
Bako-composite	5.34a-f	15.33a-c	58a	2.67
Gutto	26.66f	34.00c	3ab	8.33
Birkata	7.34b-f	15.33a-c	51ab	3.67
KCB	10.66b-f	14.67a-c	51ab	5.33
Alamura-early	4.66b-f	16.00a-c	50ab	2.33
Beletech	4.00a-d	18.67a-c	56ab	2.00
H-501	4.00a-d	6.67a-c	57a	2.00
H-8151	1.00ab	7.33ab	58a	2.00
H-625	6.00a-e	7.33ab	56ab	3.00
K-synth.II	13.34c-f	16.00a-c	56ab	6.67
Pop.43	18.46ef	16.67a-c	48b	6.33Ns
Cv(%)	19.8	17.75	26.96	62

All means followed by the same letter(s) are not significantly different from each other at 5% level (DMRT)

Table 2. Response of maize varieties to S. cerealella in free choice test, 1993.

Variety	Mean F1 moths	Mean percent kernel damage	Mean development period	Index of susc.
A-511	8.33ab	24.00cde	51ab	1.81
Gutto-Lmsc5	19.67ab	62.33h	48b	4.62
Kcc	29.33ab	42.67g	43b	3.39
Pool-9A	28.00ab	17.00a-e	55ab	2.65
UCB	2.67a	10.67ab	56ab	2.51
EV-1	4.00ab	21.00de	56ab	1.08
Katumani	30.33ab	49.33h	56ab	2.63
E.A.H.75	5.67ab	23.67ef	57a	1.32
Aba-Bako	19.67ab	24.67ef	49b	2.66
Bako-composite	19.33ab	21.00b-e	52ab	2.47
Gutto	24.33ab	27.00ef	66a	2.09
Birkata	11.33ab	16.67a-e	56ab	1.89
KCB	26.00ab	20.00a-d	50ab	2.83
Alamura-early	34.33b	43.67g	58a	2.66
Beletech	14.67ab	34.67fg	61a	1.92
H-501	15.00ab	10.33abc	60a	1.95
H-8151	14.33ab	6.67a	58a	1.98
H-625	15.00ab	20.33cde	61a	1.93
K-synth.II	29.67ab	42.67g	59a	2.51
Pop.43	14.00ab	40.33g	57b	0.75Ns
Cv (%)	27.75	20.44	28.61	54

All means followed by the same letter(s) are not significantly different from each other at 5% level (DMRT)

Table 3. Response of maize varieties to *S.cerealella* in no choice test, 1993.

Variety	Mean number of F1 moths	Mean percent kernel damage	Mean percent weight loss
H-6151	5.67a	3.33a	1.08ab
H-501	13.67b	15.00a	1.97a-d
pool-9A	38.33b	40.00bcd	2.44a-d
Gutto	19.00b	23.00ab	1.99a-d
UCB	44.33b	51.67cd	5.62cde
H-625	32.00b	28.67abc	4.71bcd
K-synth.II	16.67b	22.67ab	0.15a
Bako comp.	42.00b	52.33cd	6.92cde
A-511	19.67b	21.33ab	1.90abc
Katumani	41.33b	51.00cd	13.34e
KCB	32.67b	42.00bcd	4.68bcd
Birkata	30.67b	50.67cd	6.81cde
Alamura-early	45.00b	59.00d	7.61de
CV.(%)	30.08	22.48	30.46

All means followed by the same letter(s) are not significantly different from each other at 5% level (DMRT).

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The Biology and Management of Sorghum Shoot Fly *Atherigona soccata* in Alemaya Area: a Review

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Abstract

Several independent studies were carried out on the biology and management of the sorghum shoot fly at Alemaya. Accordingly, the *sorghum shoot fly, Atherigona soccata Rondani* was identified as the principal shoot fly pest of sorghum. The shoot fly occurred throughout the year and aestivation or diapause were not observed. Under Alemaya conditions as many as 10 overlapping generations are produced per year. Survival during the off-season took place on wild hosts such as *Sorghum arundinaceum*, *Sorghum aethiopicum* and Sorghum verticilliflorum, and sorghum stubble. Seasonal abundance of the shoot fly was significantly correlated with relative humidity, total rainfall, temperature and availability of sorghum seedlings.

Cultural practices, resistant varieties, natural enemies and systemic insecticides were identified as the major management options for the Alemaya area. Cultural practices included adjustment of planting time and density, destruction of crop residues and alternative hosts, and rouging of damaged plants. Antixenosis, antibiosis and tolerance were identified in the local sorghum as the three modalities of resistance useful in the management of the shoot fly. Out of 99 entries tested, 15 genotypes showed antixenosis, 54 showed antibiosis and 24 showed tolerance. Three natural enemies, i.e. *Oxybelus* sp. (Sphecidae), *Neotrichophoroides* nyemitawus (Rohwer) (Eulophidae) and Opius sp. (Braconidae) were also identified from the shoot fly. Among the insecticides tested, the systemic insecticides particularly carbofuran (1.5 kg/ha) applied as granules in seed furrows gave the best control of the shoot fly.

Introduction

The sorghum shoot fly, *Atherigona soccata Rondani* belongs to the genus *Atherigona*, family Muscidae and order Diptera. It was known by the name *Atherigona varia* var soccata until Pont (1972) recognized *A. soccata* and *A. varia* as discrete species. *A soccata* is the principal shoot fly pest of sorghum known to cause an estimated loss of US $337 million worldwide in the grain and stover yield of sorghum per annum (ICRISAT, 1991).

In Ethiopia, the sorghum shoot fly is one of the major insect pests of sorghum (Hill, 1989). It is distributed through out the sorghum growing areas of the country. But it is most serious in Hararghe (Theodros, 1982), Jimma (Mekuria Tadesse, personal communication), Shewa (Plotnikov & Girma, 1988) and Metekel areas. In the Hararghe region, it is known to occur in all altitudes and ecological zones where sorghum is grown (Theodros, 1982).

In the past control of the shoot fly generally depended on use of insecticides and early planting. However, recently, the trend has been towards the integrated management of this pest. In Ethiopia, little information existed for most areas except for Alemaya and Ambo. The objective of this paper is, therefore, to synthesize the results of several independent studies carried out on the biology and management of the shoot fly and make the information available to users.

Biology

The life history. The life history of the shoot fly was studied by Theodros (1982) at Alemaya. To examine the possibility of pupal diapause in the off-season a study was also carried out by Sileshi and Lakra (1994). According to these studies, adult males and females lived for an average of 7 and 17 days, respectively. The preoviposition period for females was 3-4 days long and a female laid on the average 238 eggs. Eggs were laid on the underside of seedlings 4-7 leaf stage or tilers. The number of eggs laid per seedling is mostly one but rarely as many as four. The egg is dull white and cigar shaped with longitudinal ridges and had an incubation period of 2-6 days at Alemaya (Theodros, 1982). The yellowish or creamy white larvae had black mouth hooks and spiracles (Hill, 1983), and passed through three larval instars. The total larval stage took an average of 13 days. Similarly, the incubation period of the egg was 25 days and the larval period was 12-15 days (average of 13 days) in Uganda (Barry, 1972).

The pupal period ranged from 9 to 25 days (16.05 $\pm$ 0.45 days) in the off-season and 11 to 19 days (15.42 $\pm$ 0.15 days) in the main season (Sileshi & Lakra, 1994). The average pupation period was 18 days. In Uganda the pupal period ranged from 3-18 days (Barry, 1972). The total life cycle was 34 days at Alemaya (Theodros, 1972). This took only 27 days in Uganda (Barry, 1972). The percentage emergence of adults was 95.46 and 96.76 in the off-season and main season, respectively. The male to female sex ration was also 1:1.3 and 1:1.7 in the off-season and main season, respectively (Sileshi & Lakra, 1994). The shoot fly produced as many as 10 overlapping generations per year (Theodros, 1982) and aestivation or diapause were not known under Alemaya conditions (Sileshi & Lakra, 1994).

Seasonal abundance. To study the seasonal incidence and abundance patterns of the shoot fly, different dates of planting were tested during the main season. Adult and immature stages were also monitored both in the main (May to November) and off-season (December to April). Adults were captured weekly with a standard sweep-net baited with meat meal. These studies showed the presence of the shoot fly throughout the year. However, infestation was more pronounced in late sown sorghum. High infestations were recorded in August and September while low infestations occurred from October to April (Theodros, 1982).

The monthly catches of *A. soccata* adults in sweep nets remained low during the off-season as compared to the main season. The adult catches generally increased steadily from May to September and declined from October to April (Sileshi, 1994).

Seasonal abundance of the shoot fly was significantly correlated with relative humidity (r = 0.416), total monthly rainfall (r = 0.389), number of rainy days (r = 0.357) in the month and availability of sorghum seedlings (Sileshi & Lakra, 1994). Similar observations were reported by Ogwaro (1979) in Kenya where fluctuations in numbers of adults were related mainly to rainfall patterns. The correlation between adult shoot fly abundance and rainfall patterns was presumably due to the fact that availability of moisture affects leaf surface wetness (LSW) which in turn affects larval movement to the leaf base and ultimate dead-heart formation (Raina, 1981; Nwanze et al. 1991).

This abundance pattern was also positively correlated with monthly mean temperature (r = 0.223) while it was significantly negatively correlated with difference between the extreme monthly minimum and maximum temperatures (r = -0.438). The lower adult population observed from November to January is presumably due to the extreme fluctuations in daily temperature and the low relative humidity. Delobel and Unnithan (1983) similarly reported that temperature significantly affected population growth potential. Peaks in the abundance of the shoot fly varied from year to year depending up on the favourability of these environmental conditions. Seasonal peaks also appeared to be highly correlated with periods of availability of sensitive stages of sorghum seedlings.

Moisture induced delay in development or synchrony in adult emergence was not observed (Sileshi & Lakra, 1994). Similar reports were made by Unnithan et al. (1985) where water stress to host plants does not induce quiescence or prolongation of larval and pupal periods in Kenya. It appears that diapause is not the likely mechanism of survival under Alemaya conditions. The possibility of non-reproductive diapause, however, needs to be investigated.

The critical period for the survival of *A. soccata* appears to be the time between December and April when sorghum seedlings of appropriate growth stages are not found. To identify the mechanism of survival of the shoot fly during this period, adults, eggs, larvae and pupae were monitored on tillers of sorghum stubble and wild sorghum species during the off-season of 1993.

The study showed that the shoot fly survives on residual off-season sprouts produced by left over stubble of various Sorghum spp. The intensity of egg deposition on three to four-leaved tillers varied from 0.4 to 0.6 eggs per tiller during the off season of 1993 as compared to 1.5 to 2.5 eggs per tiller during the main crop season (May to November). Oviposition was positively correlated with dead heart formation. In different months infestation by the shoot fly led to formation of 'dead-hearts' in 3.0 to 56.8 percent of the ratoon tillers, the minimum and maximum incidence being in varieties IS 9434 and ETS 3235, respectively. ETS 3235 appeared to produce more tillers that were subsequently attacked after the main stems are harvested and thus supported large populations of the flies while some others like Muyra and IS 3494 had very low percentage of tiller damage during the off-season (Table 1). It appears that alternative hosts, off-season sprouts and tillers of sorghum support a small population of the shoot fly that carries-over to the main season. Granados (1972) reported similarly observations in Thailand.

Alternative hosts. To identify the alternative hosts of the shoot fly, several graminaceous plants showing dead-hearts were collected, trimmed and maintained in emergence cages until adult shoot flies emerged and the host plants were then identified. Accordingly sorghum species (*Sorghum arundinaceum*, *S. aethiopicum* and *S. verticilliflorum*) were the only known hosts of the shoot fly. The permissive weed *S. arundinaceum* readily hybridizes with the crop sorghum leading to an intermediate population called 'Shattercane'. A moderately high percentage of the tilers and seedlings of this population was attacked during the study period (Table 1). *A. soccata* was also recorded once from barley and maize at Alemaya.

Pont (1972) listed the hosts recorded by various authors as follows: *Andropogon sorghum*, *Brachiaria reptans*, *Cymbopogon citratus*, *Cynodon dactylon*, *Desmostachia bipinnata*, *Diachanatum annulum*, *Digitaria ascendens*, *Echnochlca procera*, *Eliusine corocana*, *Eliusine indica*, *Panicum milaceum*, *P. miliare*, *Pennisetum typhoides*, *Setaria glauca*, *Sorghum aethiopicum 1*, *Sorghum halpense*, *sorghum verticilliflorum*, *Triticum aestivum* and *Zea mays*. Even though most of these plants were found at Alemaya they were not attacked by *A. soccata*. Other *Atherigona* were identified from most of these plants: *A. rubricornis* from *Brachiaria* and *Setaria*, *A. laevigata* from *Cynodon* and *A. conigera*, *A. trapezia*, *A. ferruginea* and *A. nagvi* from *Digitaria* and *A. anguistiloba* from *Triticum* (Sileshi, 1994). The author believes that there has been possible misidentifications of the shoot flies in most of the hosts listed above. Pont (1972) had similar doubts of the hosts records for *A. soccata*.

Crop loss. Though quantitative data do not exist for Alemaya area, seedling infestation was recorded to reach up to 90 percent (Theodros, 1982). Losses and reduction in grain yield were also known to reach high proportions elsewhere (Mote, 1986). At Ambo, Plotnikov and Girma (1988) estimated the economic threshold level on the local sorghum variety IS 9302 to be 14.94 and 8.97 percent dead-hearts for 5 and 3 percent yield losses, respectively.

Table 1. Extent of infestation by *A. soccata* in varieties of sorghum in the off-season and the main crop season in 1993.

Variety	Mean no. eggs\ seedling		No. tiller observed	No. tillers attacked	% tillers attacked	
	Main season	Off-season	Off-season	Off-season	Main season	Off-season
ETS 3235	1.5	0.6	2911	1654	70.8	56.8
Muyra	2.5	0.5	1861	242	62.7	13.0
IS-9434	1.9	0.4	2200	67	68.4	3.0
Shattercane	2.5	0.6	2013	739	68.4	36.7

Pest Management

Studies were carried out to identify management strategies for the sorghum shoot fly by Tessema (1971), Theodros (1982) and Sileshi (1994). Results of these studies and relevant information from review of literature are presented below.

Destruction of crop residues and alternative hosts. A study on the off-season survival of the shoot fly (Sileshi & Lakra, 1994) conclusively showed that sorghum stubble and alternative hosts like *S. rundinaceanum* and *S. verticilliflorum* support shoot fly populations in the off-season. Accordingly, it was recommended that sorghum stubble be ploughed under immediately after crop harvest and weedy sorghum species be removed before flowering to reduce the chances of early infestation which develop on subsequent seedlings in the following crop season (Sileshi & Lakra, 1994).

Adjusting planting date. Since the shoot fly remained active throughout the year, adjustment of planting time was found to be the best practice to avoid heavy infestations. For three different sowing dates, the percentage of seedlings attacked varied from 4% for early sowing to 30-40% for late sowing. At Alemaya, sorghum plantings done up to 29 April showed minimal damage whereas plantings done as late as 29 May suffered the highest damage (Theodros, 1982). Early planted sorghum escaped significant injury by the fly because of low adult fly populations. Similarly, in West Africa, late sown sorghum plants were the worst attacked (Hill, 1983). Therefore, for Alemaya area, it is recommended that plantings be done immediately with the commencement of the rains in early May. Staggered plantings or plantings scattered in time must also be avoided since these could spread the infestation.

Adjustment of Planting Density

To examine the effect of plant density, a study was carried out at Alemaya in 1993 and 1994. Accordingly, the highest and lowest percentage of dead-hearts was observed in sorghum planted at 30 and 7.5 cm between plants, respectively. With increase in intra-row spacing from 7.5 cm to 15 cm, there was 25.7% increase in dead-hearts. Similarly with increase from 7.5 cm to 30 cm, there was 45.8% increase in dead-hearts. The percentage of dead-hearts was negatively correlated ($r = -0.76$, $P = 0.014$) with sorghum population (Sileshi et al., 1995). Generally, increased plant density appeared to reduce damage by the shoot fly. Similar observations were reported by Delobel (1982). On the other hand, Davies and Reddy (1981) observed that the number of eggs laid was highest per unit area at high plant densities. It is recommended that optimum planting densities that will reduce damage by the shoot fly but that will not compromise yields be worked out in detail for varieties under cultivation.

Roughing

Though systematic work has not been carried out on this aspect of control at Alemaya, there are circumstantial evidences from elsewhere indicating the value of this practice in the management of the shoot fly. The age old practice of planting with increased seed rates (10-15% more than the desired) and removal and destruction of infested seedlings was an important cultural practice. The roughed plants can be used as fodder for animals. This, however, requires hand labor and may be a tedious job.

Intercropping

Intercropping sorghum with other crops is a wide spread farmers practice in the Hararghe region. Farmers intercrop sorghum as a means of income diversification and risk aversion (Storck et al., 1991). Intercropping has been studied sufficiently and there is a considerable body of evidence showing that it can be used to reduce incidence of pest insects (Tingey & Lamont, 1988). Infestation by *A. soccata* was reported to be lower when sorghum was raised in association with leguminous crops (Amoako-Atta & Omolo, 1983; Amoako-Atta et al., 1983). To examine the effect of intercropping on the incidence of the shoot fly a study was carried out at Alemaya in 1993 and 1994. Row arrangement of sorghum with beans in intercropping significantly affected damage by the shoot fly. Generally, damage was higher in intercropped systems than sole crops. But 2 sorghum : 2 bean and 3 sorghum : 3 bean intercropping was not significantly different from sole sorghum (Table 2) and there was no comparative advantage of intercropping over sole cropping in terms of shoot fly control (Sileshi, 1994). Similar observations were reported by Dissemond and Weltzien (1986) from Kenya and Natarajan et al. (1991) from India. On the other hand, Kato et al, (1982) reported lower incidence of the shoot fly in intercropping in Tanzania. Therefore, there is a need to assess intercropping systems before making concrete recommendations.

Varietal Resistance

In a total of 99 sorghum entries screened for resistance to the sorghum shoot fly in the 1992 and 1993 crop seasons three modalities of resistance (antixenosis, antibiosis and tolerance) were identified under the agro-climatic conditions of Alemaya (Sileshi, 1994).

Accordingly 15 genotypes showed antixenosis and were consistently non-preferred for oviposition. Average percentage of plants with eggs ranged from 32.4 in ICSV 708 (a resistant ICRISAT variety) to 97.4 in Swarna (a susceptible ICRISAT variety). The average number of eggs per plant ranged from 0.5 (in ICSV 707) to 4.1 (in Wb 77) (Table 3).

Percentage of dead-hearts (Table 4), taken as a measure of antibiosis resistance, ranged from 12.1 (in ICSV 714) to 80.9 (in Swarna) and these significantly differed between varieties. Fifty one entries and 3 check varieties consistently showed high resistance to the shoot fly (%DH < 40).

Table 2. Effect of intercropping sorghum with beans on oviposition and seedling injury by the sorghum shoot fly at Alemaya during 1992 and 1993 crop seasons. (*S. sorghum, B; bean*)

Treatment	No. of eggs/10 plants			Percentage of dead-hearts/plot		
	1992	1993	Mean	1992	1993	Mean
Arrangement						
Sole S	5.0	5.2	5.1	8.9b	24.1b	15.8b
1S : 1B	3.7	6.8	5.1	6.1b	45.9a	25.8a
2S : 2B	4.4	6.7	5.4	12.8a	28.8ab	20.2ab
3S : 3B	4.2	5.4	4.7	13.7a	30.1ab	21.4ab
LSD	NS	NS	NS	3.6	10.5	5.4
Spacing (cm)						
7.5	5.3a	6.8a	6.0a	6.2c	24.1b	13.9c
15.0	4.6a	6.3ab	5.4a	9.6b	31.6b	19.4b
30.0	3.2b	5.0b	4.1b	15.8a	40.9a	27.4a
LSD	0.9	1.8	0.9	3.1	9.1	4.7
Years						
1992			4.5b			10.2a
1993			6.3a			32.0b
LSD			0.8			13.8

Means followed by the same letters in the same column are not significantly different at P = 0.05.

The average number of effective tillers per plant (ANET) was taken as a measure of tolerance (Table 5). The ANET ranged from 0.1 (in 89 AN 5009) to 3.9 (in CSH 9). Twenty four entries (with ANET > 2.0) consistently showed tolerance to the shoot fly. Genotypes like Jaru # 5 synchronously produced effective tillers after attack by shoot fly. Tiller survival was higher in most varieties in 1993 than it was in 1992 probably due to the better moisture condition in the later year. Tiller formation may not necessarily compensate for grain yield loss under conditions of moisture stress (Panchabhavi et al., 1989) and apical dominance is preferred under such conditions. This is often true in areas like the Erer valley (Eastern Hararghe) where moisture is always limiting. The average percent of plants with eggs, percent of plants with dead hearts and number of effective tillers varied from year to year; the higher being in 1993. These depended on the amount of precipitation in the year and the population pressure of the shoot fly.

Table 3: Ovipositional responses of sorghum shoot fly to sorghum varieties screened for resistance at Alemaya, 1992–1993 (% plants with egg)

Entry	%PE
1. ICSV 708	32.4
2. 89 AN 5009	35.2
3. Acc # 206922	39.8
4. ETS 1446	39.8
5. ICSV 714	40.4
6. 89 AN 5003	44.4
7. ETS 377	44.7
8. ICSV 705	45.2
9. Hararghe Coll # 2	45.3
10. ETS 804	46.6
11. Acc # 70583	47.8
12. Derived from DSBM3	48.1
13. ICSV 713	48.4
14. 89 AN 5030	49.0
15. ETS 591	49.5
Checks	
1. CSH 1	42.2
2. ETS 4946	53.7
3. ETS 2752	57.5
4. ETS 3235	63.5
5. Muyra (Red)	66.2
6. Al 70	73.0
LSD (at a = 0.05%):	
Between varieties & checks	40.3
Among varieties	47.5
Among checks	26.4
CV (%)	31.9
Variance	2103.1

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ICRISAT genotypes ICSV 705, ICSV 708, ICSV 713 and ICSV 714 and the local genotypes ETS 591 and Acc # 206922 possessed both resistance to oviposition and antibiosis. Similarly, ICRISAT genotypes IS 2291, IS 5480, ICSV 705, ICSV 708, ICSV 713, ICSV 714 and the local genotypes PGRC/E Acc # 166 and 86 MW # 5228 also combined antibiosis and recovery resistance. Unfortunately, some of the ICRISAT varieties like IS 5480, ICSV 708, ICSV 713, ICSV 2291 and ICSV 88088 show notable sterility. Some ICRISAT varieties like ICSV 705, ICSV 88088, ICSV 714, IS 5480 and Ethiopian varieties like 87 Al 4016, Acc # 206922 and 89 AN # 5004 germinated and established themselves faster than the others. These varieties subsequently had lower percentage of oviposition and dead-hearts. This is probably due to the fact that genotypes that grow faster accumulate antibiotic factors faster.

Though ovipositional non-preference and tolerance are known to be greatly influenced by the level of shoot fly population and growth conditions of the plant may not always be predictable in various locations (Raina, 1985). They seem to be valuable means to produce acceptable yields in spite of attack by the shoot fly (Dogget, 1972). Antibiosis resistance is perhaps the most useful form for non-preference can break down when the insect does not have a choice. Since Ethiopia is believed to be the center of origin of sorghum, the genetic diversity in this country is enormous. Therefore, there is a greater scope for use of varietal resistance in the management of the sorghum shoot fly.

Natural Enemies

Parasitoids and predators are reported from different life stages of the shoot fly in different countries. To identify the kinds of natural enemies of the shoot fly, studies were carried out at Alemaya from 1992 to 1994. Three Hymenopterous species: *Oxybelus* sp. (Sphecidae), *Neotrichoporoides nyemitawus* (Rohwer) (Eulophidae) and *Opius* sp. (Braconidae) were identified from the sorghum shoot fly. *Oxybelus* sp. was observed to capture adult *A. soccata* at rest. This was very common during the second and third weeks after the rains when large numbers of wasps appear. The larvae of *A. soccata* were also seen to be parasitized by *N. nyemitawus* and *Opius sp. N. nyemitawus* was the most important among these and it was recorded from 4.54 percent in the off-season and 3.24 percent of the pupae in the main season. In the present work, the collection and identification of the natural enemies was limited to the Alemaya area. There is a strong need to collect, identify and catalogue the natural enemies. There is also a strong need to conserve these friends of the farmer by making the habitat suitable for their multiplication.

Chemical Control

Much of the information regarding conventional use of insecticides against the shoot fly is conflicting. Some insecticides were not cost effective for subsistence farmers (Raina, 1985), others have encouraged resurgence of treated populations (Davies & Jowet, 1966). Generally, seed treatment and granular applications have given better control with less environmental problems (Mote, 1982).

Table 4. Varietal differences in antibiosis resistance of sorghum genotyeps to sorghum shoot fly at Alemaya, 1992–1993 (% dead-hearts)

Entry	% dead-heart
1. ICSV 714	12.1
2. 89 AM 5616	18.1
3. Hararghe Coll # 3	18.6
4. ICSV 708	19.5
5. ICSV 705	19.8
6. ICSV 88088	25.2
7. IS 5480	25.7
8. Al Obs Mur Acc # 2002b	25.9
9. 87 Al 4016	26.4
10. IS 18551	26.8
11. IS 2291	27.4
12. ETS 591	27.4
13. 89 AN 5009	28.3
14. ETS 721	29.0
15. Acc # 206922	29.7
16. ICSV 713	29.9
17. 86 MW # 5228	30.0
18. PGRC/E Acc # 166	30.3
19. 85 MW # 5606	30.4
20. 89 AN 5003	31.2
21. 89 AN 5030	32.0
22. IS 9302	32.6
23. Al Coll 1988 P # 20	32.8
24. Al ON P # 165-1	32.9
25. ETS 804	32.9
26. Hararge Coll # 2	32.9
27. Acc # 72046	33.3
28. ETS 818	33.5
29. ETS 1446	33.7
30. Derived from DSBM3	34.0

Table 4. Contd.

Entry	% dead-heart
31. 85 PGRC/E Acc # 137	34.1
32. ETS 2752 X 82 HPYT-222-3	34.2
33. GPC NUR P # 52	35.0
34. Al Obs Nur P # 32	35.1
35. ETS 913	35.2
36. Hararghe Coll # 1	35.3
37. ETS 377	35.5
38. ETS 1176	35.6
39. ETS 576	35.7
40. Al Coll 1988 P # 16	35.7
41. Acc # 70583	35.8
42. PGRC/E 73249	36.2
43. ETS 0738	36.4
44. ETS 2113	37.1
45. ETS 789	37.8
46. 89 AN 5023	38.0
47. Derived from DSBM2	38.0
48. ETS 2752 x 82HPYT-2 #22-4	38.2
49. ETS 3135	38.4
50. 87 AN 5011	38.9
51. ETS 639	39.4
52. IS 9323	40.5
53. Collection # 8	40.5
54. ETS 2247	41.0
Checks	
1. CSH 1	34.1
2. Muyra (Red)	37.8
3. ETS 2752	38.7
4. ETS 4946	42.3
5. ETS 3235	47.0
6. Al 70	49.1
LSD (at = 0.05%)	
Between varieties & checks	31.9
Among varieties	37.6
Among checks	20.9
CV (%)	43.4
Variance	1358.0

Table 5. Varietal tolerance differences among sorghum genotypes to attack sorghum shoot fly attack at Alemaya, 1992–1993 (average number of effective tillers per plant)

Entry	Average no. effective tillers per plant
1. CSH	3.9
2. Jaru # 5	3.8
3. Swarna	3.8
4. CSH 6	3.6
5. CSH 5	3.2
6. 85 MW # 5354	3.1
7. ETS 1176	2.7
8. IS 2291	2.7
9. IS 9302	2.7
10. IS 5480	2.7
11. PGRC/E # 73068	2.6
12. IS 9415	2.6
13. ICSV 714	2.6
14. Shattercane	2.3
15. 87AN 4026	2.3
16. ICSV 708	2.3
17. ETS 02454	2.2
18. 87 AI 4008	2.2
19. ICSV 705	2.1
20. 87 AN 5057	2.1
21. 86 MW # 5228	2.1
22. 89 AN 5030	2.1
23. ICSV 713	2.1
24. Acc # 71076	2.1
25. PGRC/E Acc # 166	2.0
Checks	
1. CSH 1	1.9
2. ETS 3235	1.5
3. AI 70	1.4
4. ETS 2752	1.3
5. ETS 4946	1.1
6. Muyra	0.9
LSD (at a = 0.05%)	
Between varieties & checks	2.2
Among varieties	1.3
Among checks	0.8
CV (%)	33.2
Variance	2.5

Studies made on chemical control of the shoot fly at Alemaya showed that carbofuran granules applied at the rate of 3 kg ai/ha was the best followed by aldicarb (Theodros, 1982). Treatment with aldicarb and carbofuran granules killed the insect and gave higher yields (Tessema, 1972). Whereas seed treatment with a soluble powder of carbofuran at 5 percent (W/W) gave satisfactory control, soil treatment with carbofuran (1.5 kg ai/ha) and phorate (1 kg ai/ha) as granules in seed furrows was the best (Tessema, 1972).

Integrated management of sorghum shoot fly necessitates study of ecology and biology of the fly. Field-based basic data in this line were presented. But there is a need for the continuous follow-up of the fly population. IPM of this pest should also involve use of a combination of two or more techniques in as compatible a manner as possible. Studies into the management of the shoot fly using resistant cultivars have shown positive leads. However, there is a need for screening of the available sorghum material in order to develop resistance sources useful in the breeding program. There is also a strong need for the study of the biology of the natural enemies in relation to the pest. Effect of cultural practices like rouging, plant density, mixed cropping, etc. must also be further investigated.

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Comparison of Some Insecticides for Effectiveness Against the Maize Weevil *Sitophilus Zeamais* (Coleoptera: Cruculionidae) on Stored Sorghum at Bako

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Abstract

The effectiveness of some insecticides for the control of the maize weevil, *Sitophilus zeamais* (Motsch.) on stored sorghum was evaluated in the laboratory at Bako Research Center in 1991 and 1992. Wood ash, neem seed and leaf were also tested. Each treatment was applied at three rates and there were four replications arranged in a completely randomized design. Mortality of adult weevils, progeny emergence, control efficacy and seed germination were used as the criteria to evaluate effectiveness between the treatments. The two years' average result indicated a highly ($P<0.0001$) significant differences among insecticides in all parameters considered. All insecticides except permetherine inflicted high mortality, low progeny emergence and high control efficacy at all rates tested. Grains treated with permethrine at the rates of 2 and 4 ppm gave a relatively low mortality, high progeny emergence and low control efficacy. Generally, the efficacy of the tested insecticides ranged between 79 and 100%. In both years wood ash, neem seed and leaf powder showed a promising potential for further investigation. Percentage seed germination in all treatments ranged between 92.5 and 99.5%.

Introduction

The maize weevil, *Sitophilus zeamais* (Motsch), is among the most common and destructive storage pests inflicting heavy damage and losses to cereals both in the field and store. About 15% weight loss has been reported on sorghum that was stored in traditional storage facilities (Yemane and Yilma, 1989). Storage losses should not be visualized only in terms of weight loss, since damaged seeds often loose their viability, quality and nutritional values (Ezueh, 1983; Okiwelu et. al., 1987).

There is a considerable scope for better use of conventional pesticides and their integration with other control measures to control storage pests (McFarlane, 1989). In Ethiopia, lindane and malathion are the most common grain protectants that have been used for many years. In 1990, we observed grains treated with lindane infested and damaged by the maize weevil in the Bako area. Survey works in different countries show that widespread malathion resistance in stored product insects and resistance to other chemicals used in stored food including fumigants to be common and rapidly increasing (White et. al., 1988). Therefore, it is timely to search as many insecticides and other traditional control measures as possible before such situation occurs. Furthermore, evaluation of promising candidate compounds for the control of insects that attack stored grain is a continuing part of research leading to the development of acceptable grain protectants. Thus, the objective of this study was to determine the protective level of some insecticides and other materials against the maize weevil, when applied as dusts at different rates to sorghum seeds in the laboratory.

Materials and Methods

The experiment was conducted at Bako Research Center Laboratory for two years (1991-1992). One hundred g of clean and disinfested sorghum grain (variety IS-9302) was placed in glass jars (250 ml capacity) and conditioned for five days in the laboratory. The moisture content of the grain was adjusted to 11 - 11.5%. In 1992 the neem seed powder treatment was replaced by neem leaf powder. Mixed wood ash was obtained at random from homestead kitchen. After five days each treatment was applied into four of the jars each containing 100 g sorghum grain and thoroughly mixed. Two days after treatment application, 30 laboratory reared (3-5 days old) weevils were placed in each jar in 1991. In 1992, 16 weevils collected from farm grain store of Bako Research center were used and kept undisturbed in the laboratory for seven days. The experiment was arranged in completely randomized design. Mortality of adult weevils was checked 1, 2, 3 and 4 weeks after infestation (WAI). Each time dead weevils were removed, counted and sexed. On the 4th week live weevils were also removed, counted and sexed. The grain samples were retained to observe the emergence of F_1 progeny. Four WAI, each treatment was checked daily and newly hatched weevils were collected for five weeks. Damage assessment was made by taking samples of 100 seeds at random from each observation and by counting the damaged seeds. For seed germination test, 100-seed samples were taken at random from each replication and these were placed in Petri-dishes containing moistened filter paper. After 10 days, the number of germinated seeds was recorded.

The efficacy level of each treatment was derived using the method of Oerill (1975) based on percent mortality of weevils in the different treatments including the untreated control.

$$\text{Efficacy (\%)} = \frac{b - c}{100 - c} \times 100$$

where:

b - Proportion of dead weevils in treated grains
c = Proportion of dead weevils in control grains

Analysis was made in two-factor completely randomized design using MSTAT computer program. Duncan's Multiple Range test was used for mean separation. Combined analysis were made excluding the neem and wood ash treatments.

Results and Discussion

Analysis of variance for various parameters, combined over years revealed significant differences between years and among insecticides, rates and some of their interactions (Table 1). There were significant ($p < 0.01$) differences in mortality and efficacy among rate x insecticide interactions but not in progeny emergence (Table 2). Except permethrine, all insecticide rates inflicted mortality of 95-100%, and the differences among them were not significant. Significantly lower (72.4%) mortality was recorded in the control treatment and it was followed by permethrine at the rates of 2 and 4 ppm which inflicted 85.8 and 93.37% mortality, respectively. Relatively higher progeny emergence was recorded in the control treatment followed by permethrine at 2 and 4 ppm (Table 2). Except permethrine at 2 and 4 ppm, all remaining rates of the different insecticides showed efficacy levels ranging from 91 to 100% and were not significantly different from one another (Table 3). Grains treated with 2 and 4 ppm of permethrine showed 62.41 and 77.44% efficacy, respectively, and were not significantly different from the remaining insecticide treatments.

Over all, there was a highly ($p<0.001$) significant difference between insecticides and the control treatment in mortality, progeny emergence, and the control treatment in mortality, progeny emergence, and control efficacy (Table 3). Significantly lower mortality and higher progeny emergence were recorded in the control treatment followed by permethrine. Mortality in the remaining treatments ranged between 96.4 and 100% and progeny emergence was kept to the minimum throughout the storage period. Except permethrine which showed about 79% efficacy, all the other insecticides exerted between 96 and 100% efficacy.

Wood ash at the rate of 1, 2 and 3% (w/w) showed higher mortality, reduced progeny emergence and higher control efficacy in both years (Table 4). In all parameters no significant difference was detected among wood ash, synthetic pyrethroids and organophosphorus insecticides. Neem seed and leaf powder also showed relatively higher mortality and reduced progeny emergence when compared to the untreated check (Table 5). Over all the control efficacy of neem seed powder and wood ash was about 34 and 98% respectively. The difference in terms of percentage seed germination among the various treatments and rates was significant ($p<0.01$). Seed germination was highest in the control treatment. In all cases however, percentage seed germination ranged between 92.5% and 99.5% and this is not low when compared to the requirement in the standard seed quality testing criteria. This study has shown that all the insecticides, wood ash and neem seed powder caused high mortality and reduced progeny emergence. According to Abraham et. al. , (1993), permethrine applied at the rate of 2 ppm on shelled maize gave efficient control of the maize weevils for about five months. In this study, however, the use of permethrine particularly at lower rates (2 and 4 ppm) was less effectiveness could be due to longer time in storage of the chemicals. On the other hand, the highest rate of permethrine showed appreciable mortality of adult weevils, reduced progeny emergence and increased control efficacy. This agrees with the findings of Abraham et. al., (1993).

Malathion has been used as grain protectant since the 1950;s but most species of stored product insects have developed resistance to it and the utility of this compound is the severely reduced (Champ & Dyte 1976). On the contrary, malathion controlled the maize weevil effectively for about four months on sorghum at all rates tested in this experiment. The use of malathion and methacrifos at lower rate (5 ppm), however, left few survivors after a month of storage period; relatively higher number of progeny were also recorded with these insecticides. Abraham *et.al.* (1993) reported similar observation on some insecticides including malathion tested on maize. However, the use of malathionate 10 and 12 ppm and methacrifos at 7 and 10 ppm showed adequate control of maize weevils for about four months. The result of this study also demonstrated the potential of deltamethrine 0.2% and 2.5% dust, malathion 1.6% _ permethrine 0.4% mixture and pirimiphos-methyl 2% dust for the control of maize weevils at all the rates tested. Thus one can use any of these insecticides at the indicated rates depending on their practical convenience, including availability and cost. Users should also avoid continuous use of a particular insecticide at lower rates. They have to use one after another or changing between the highest and the lowest rates of the specific insecticides.

It may be suggested that candidate compounds be evaluated against other pest species on other cereals in storage. Moreover, it is necessary to determine the level of pesticide residue left behind. Wood ash and neem showed a promising potential that deserves further investigation. Kyamanywa (1990) demonstrated the use of wood ash in protecting been seeds against bruchids in store. The control potential of neem seed powder on the maize weevil on maize has also been reported (Abraham *et.al.* 1993). Though neem seed powder was less effective than wood ash and other insecticides tested, in this experiment, 3% (w/w) of seed powder gave about 49% efficacy. This agrees with the efficacy of 41% reported by Abraham et. al., (1993) for 2% (w/w) neem seed powder applied on maize. Considering the unavailability, costliness and toxicity of synthetic grain protectant insecticides in developing countries, using traditional grain protectants offers safe, easily available and cheap methods against crop pests like weevil. From this point of view, wood ash and neem could play an important role in protecting sorghum grains against the maize weevil.

Table 1. Analysis of variance for mortality, progeny emergence and efficacy

Source of variation	df[2]	Mortality (%)	No. Progeny emerged	Efficacy (%)
Year	1 (1)	***	***	***
Treatments	7 (6)	***	***	***
Year X Treatments	7 (6)	***	***	***
Rates	2 (2)	**	*	***
Year X Rates	2 (2)	**	NS	***
Treatments X Rates	14 (12)	**	NS	***
Year X Treatments X rates	14 (14)	**	NS	***

[1] Analysis was made on arcsine transformed values for mortality and efficacy and on square-root transformed values for progeny emergence.
[2] Numbers in parenthesis are df for percentage efficacy
*** Significant ($p < 0.001$); ** Significant ($p < 0.01$); * Significant ($P = 0.05$); NS Nonsignificant ($P = 0.05$)

Table 2. Effect of insecticidal dusts on adult mortality and progeny emergence of maize weevil and their control efficacy on sorghum (two years average, n = 8[1])

Insecticidal dusts tested	Rates (ppm)	Mortality (%)	Progeny emerged	Efficacy (%)
deltamethrine 0.2%	0.5	100.00^{a}	0.88	100.00^{a}
	1.0	100.00^{a}	0.13	100.00^{a}
	2.0	100.00^{a}	0.38	100.00^{a}
deltamethrine 2.5%	1.0	100.00^{a}	0.13	100.00^{a}
	2.0	100.00^{a}	0.25	100.00^{a}
	3.0	100.00^{a}	0.38	100.00^{a}
malathion 1%	5.0	99.58^{a}	2.75	98.49^{a}
	10.0	100.00^{a}	0.38	100.00^{a}
	12.0	100.00^{a}	0.25	100.00^{a}
malathion (1.6%) + permethrine (0.4%)	5.0	100.00^{a}	0.13	100.00^{a}
	7.0	100.00^{a}	0.13	100.00^{a}
	10.0	100.00^{a}	0.13	100.00^{a}
methacrifos Dp 2%	5.0	99.44^{a}	3.13	94.34^{a}
	7.0	100.00^{a}	0.25	100.00^{a}
	10.0	100.00^{a}	0.13	100.00^{a}
permethrine 1%	2.0	85.81^{c}	4.00	62.41^{b}
	4.0	93.77^{b}	4.13	77.44^{a}
	6.0	99.13^{a}	0.63	96.86^{a}
pirimiphos-methyl 2%	5.0	95.34^{ab}	0.13	91.17^{a}
	7.0	100.00^{a}	0.25	100.00^{a}
	10.0	99.60^{a}	0.13	98.54^{a}
Control	-	72.39^{d}	6.63	-
SE (+)		1.31	1.16	3.09
		4.52	50.63	9.10
CV (%)[2]		**	NS	***

[1]Means followed by same letter within a column are not significantly different (DMRT[** = $p<0.01$, *** = $p<0.001$, NS = nonsignificant $p>0.05$).;
[2]arcsine transformed for mortality and efficacy while square-root transformed for progeny emergence.

Table 3. Effect of insecticidal dusts on adult mortality and progeny emergence of the maize weevil and their control efficacy on sorghum, 2 yr mean, main effect, n = 12).

Insecticidal dusts tested	Mortality (%)	No. progeny emerged	Efficacy (%)
deltamethrine 0.2%	100.00a	0.46c	100.00a
deltamethrine 2.5%	100.00a	0.25c	100.00
malathion 1%	99.86a	1.13bc	99.49a
malathion (1.6% + permethrine (0.4%)	100.00a	0.13c	100.00a
methacrifos Dp 2%	99.48a	1.17bc	98.11a
permethrine 1%	92.91b	2.92b	78.91b
pirimiphos-methyl 2%	96.38a	0.17c	96.57a
Control	72.39c	6.63a	-
SE (+)	0.759	0.670	1.786

[1]Means followed by the same letter within a column are not significantly different (DMRT [$p<0.001$).

Table 4. **Effect of neem and wood ash** on adult mortality and progeny emergence of maize weevil and control efficacy on sorghum (n = 4).

Treatments	Rates (w/w)	1991[a]			1992		
		Mortality (%)	Progeny emerged (No)	Efficacy (%)	Mortality (%)	Progeny emerged (no.)	Efficacy (%)
Neem seed powder	2	59.48cd	4.00	27.81d	-	-	-
	3	72.63c	6.00	48.82cd	-	-	-
	4	63.27cd	9.25	25.07d	-	-	-
Neem leaf powder	2	-	-	-	100.00	0.00	100.00
	3	-	-	-	100.00	0.00	100.00
	4	-	-	-	100.00	0.00	100.00
Wood ash	1	100.00a	0.00	100.00'	100.00	0.75	100.00
	2	95.27ab	0.00	90.35ab	100.00	0.00	100.00
	3	100.00a	0.75	100.00a	100.00	1.00	100.00
		50.98d	9.00	-	93.8	4.25	-
SE(+)		3.48	2.29	6.33	0.31	0.25	4.36
CV (%)		7.14	57.43	12.96	1.48	24.6	8.8
Treatment means[b]							
Neem seed powder		65.13'	6.42"	33.9'	-	-	-
Neem leaf powder		-	-	-	100.00a	0.0'	100.00
Mixed wood ash		98.42'	0.25'	96.78'	100.00'	0.58'	100.00

[a] Means followed by the same letter within a column are not significantly different (DMRT [P<0.01])

[b] Means followed by the same letter within a column are not significantly different (DMRT [P<0.01])

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Evaluation of Some Botanicals Against the Maize Weevil (*Sitophilus zeamais* Motsch.) on Stored Sorghum at Bako

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Abstract

Crude leaf and/or seed, flower powder of 17 plant species belonging to 13 families were compared with pirimiphos-methyl 2% dust and the untreated check for their toxicity to adult *Sitophilus zeamais* at Bako. Mixed wood-ash, maize cob-ash and cow dung were also included in the test. Except pyrethrum and primiphos-methyl, all botanicals, wood-ash, maize cob-ash and cow dung were tested by admixing 5% (w/w). Pyrethrum and pririmiphos-methyl were applied at the rate of 2% (w/w) and 10 ppm, respectively. The treatments were arranged in completely randomized design with four replication. Among the treatments, eight of them inflicted 58-88% mortality in the following order Phytolacca dodecandra leaf powder (58%) < Datura stramonium leaf powder (61%) < Nerium oleander leaf powder = Phytolacca dodecandra seed powder = pirimiphos-methyl = mixed wood ash (66-72%) < pyrethrum flower powder (88%). Three plant products caused < 30% and eighteen of them between 31 and 50% mortality. Significantly lower numbers of progeny were recorded in pyrethrum flower powder, mixed wood-ash and pirimiphos-methyl treated grains followed by Phytollacca dodecandra seed powder within four months of storage period. Number of progeny emerged on the remaining treatments ranged between 184-763 and were not significantly different from the control. Seed germination was not affected by any of the treatments. This study showed the potential of some botanical plants for the control of S. zeamais on sorghum.

Introduction

Environmental consideration in integrated pest management has posed new challenges to scientists in developing pesticides effective against target species, but create minimal adversity to non-target ones (Williams et al., 1993). Historical usage of neem tree, tobacco and pyrethrum as control agents has encouraged to focus attention on alkaloids, flavonoids, terpenoids and other compounds which plants have evolved for millions of years for defending themselves against being overgrazed by insects. To date, over 1600 plant species have been identified to possess insecticidal activity (Michael et al., 1985).

The need for effective, cheap and safe grain protectants is perhaps more important for the developing countries like Ethiopia, where pesticides, are unavailable, costly and also because of their toxicity to the user and the environment. Furthermore, the use of insecticides alone has not, in a majority of cases, solved the problem of storage pests. This would appear to be due to insects developing resistance against insecticides (Dick, 1988). Using few or no agro-chemicals and relying on traditional grain protectants and the use of biological control offer environmentally friendly and more economic approach for many resource-poor farmers. Farmers in Ethiopia used local herbs, spices and mixtures to reduce insect infestations in store (Yemane and Yilma, 1989). The effectiveness of these bio-pesticides, however, has not scientifically been studied adequately. Thus, the bio-potentials of both endemic and introduced plants in the country require detail investigation. The present study was undertaken with this objective in mind.

Materials and Methods

The seventeen plant species belonging to 13 families and selected for the present study and the plant parts used are indicated in Table 1. The required plant parts and cow-dung were collected and dried in the sun. Then they were separately crushed and powdered using a local mortar and pestle. Mixed wood ash was obtained at random from homestead kitchen while maize cob ash was prepared for the purpose of this experiment. Once the materials were powdered, each was sieved over a 250 um sieve to obtain the finest particles. These were kept in plastic bags and stored at room temperature and relative humidity until use. Dried pods and fresh leaves of plants to be used without powdering were kept in the refrigerator until use. Except pyrethrum and pirimiphos-methyl which were used at the rate of 2% (2/2) and 10 ppm, respectively, all the other treatments were tested at the rate of 5% (w/w) and 10 ppm, respectively, all the other treatments were tested at the rate of 5% (w/w). In addition to the untreated control, pirimiphos-methyl 2% dust was used as a standard check. Each treatment was applied into glass jars (250 ml capacity) each containing 100 g of cleaned and disinfested sorghum seeds and thoroughly mixed. The moisture content of the grain was 11.5%. Five days after grain treatment; 30 adult maize weevils collected from Bako Research Center farm stored grain were introduced into each jar which was supplied with a lid allowing ventilation. These were kept undisturbed for 7 days in the laboratory where temperature and relative humidity were not controlled. The experiment was arranged in completely randomized design with four replication. Mortality of adult weevils was checked at 7, 14, 21 and 28 days after infestation (DAI). Each time, dead weevils were removed counted and sexed. At the 28th day live weevils were also removed, counted and sexed. The grain samples were retained for observation on the emerging progeny weevils until the 16th week after infestation (WAI). Progeny emergence was checked every week starting form the 5th WAI. At the 16th week after emergence, samples of 100 seeds were taken at random from each replication of each treatment for germination test. The seeds were placed in Petri-dishes containing moistened filter paper and the number of germinated seeds was recorded after ten days.

Data were subjected to statistical analysis after transformation. Duncan's multiple range test was used for mean separation.

Table 1. List of treatments tested against maize weevil on stored sorghum, Bako (1993/94)

No.	Treatments[1]	Family	Common name	Parts used[2]
1	*Chrysanthemum*[a,b]	Compositae	Pyrethrum	FP
2	*Mixed wood ash*[a]	-	Wood ash	FnP
3	*Phytolacca dodecandra*[b]	Phytolacaceae	Endod (local name)	SP
4	*Nerium oleander*[b,c]	Apocynaceae	Oleander	LP
5	*Datura stramonium*[b,c]	Solanaceae	Thorn apple	LP
6	*Phytolacca dodecandra*[b]	Phytolacaceae	Endod	LP
7	*Cow dung*[a]	-	Cow dung	FnP
8	*Croton macrostachys*	-	Bisana (local name)	LP
9	*Melia azederach*[a]	Meliaceae	Persian lilac	LP
10	*Lantana camara*[a,c]	Verbenaceae	Lantana	SP
11	*Lantana camara*[a,c]	Verbenaceae	Lantana	LP
12	*Tagetus minuta*[a]	Compositae	Mexican marigold	LP
13	*Capsicum sp.*[a]	Solanaceae	Hot pepper	UP
14	*Eucalyptus globulus*[b]	Myratceae	Eucalyptus	UL
15	*Maize cob ash*[a]	-	Maize cob ash	FnP
16	*Melai azedrach*[a]	Meliaceae	Persian lilac	SP
17	*Capsicum sp.*[a]	Euphorbiaceae	Castor	SP
18	*Capsicum sp.*[a]	Solanaceae	Hot pepper	PP
19	*Datura Stramonium*[a,b]	Solanaceae	Thorn apple	SP
20	*Eucalyptus globulus*[b]	Myratceae	Eucalyptus	LP
21	*Capsicum sp.*[a]	Solanaceae	Chilli pepper	PP
22	*Schinus molle*[a]	Anacardiaceae	Pepper tree	SP
23	*Nicotina tabacum*[a,c]	Solanaceae	Tobacco	LP
24	*Azadrichta indica*[a,b,c]	Meliaceae	Neem tree	LP
25	*Allium sativum*[a,b,c]	Alliceae	Garlic	BP
26	*Species*[d]	-	-	FPP
27	*Allium sativum*[a,b,c]	Alliceae	Garlic	UB
28	*Capsicum sp.*[c]	Solanaceae	Chilli pepper	UP
29	*Pirimiphos-methyl 2%*		Pirimiphos-methyl	Dust
30	*Untreated control*			-

[1] Selection criteria: insecticidal property, traditional medicinal value, chemotaxonomy, insect attack absence

[2] FP, flower powder; SP, seed powder; LP, leaf powder; FNP, fine ash powder; PP, pod powder; BP, bulb powder; UB, unbroken bulb; UP, unbroken pods; P, fine cow dung powder; UL, unbroken leaf; FPP, flower pod powder

Results and Discussion

There were a highly ($p < 0.001$) significant differences among treatments in cumulative percentage mortality of adult weevils 28 DAI (Table 2). Pyrethrum (FP) inflicted the highest mortality followed by mixed wood ash, *Phytolacca dodecandra* (SP and *Nerium oleander* (LP). These treatments were not different from pirimiphos-methyl 2% dust and from one another (Table 2). Species A (FPP), *Allium sativum* (UB), *Capsicum* sp. (Chilli pepper) inflicted lower mortality levels than what was observed on the untreated control and they were followed by *Allium sativum* (BP). *Datura stramonium* (LP) and *Phytolacca dodecandra* (LP), caused fairly high (58-61%) mortality followed by *Croton macrostachys* (LP), and cow dung which inflicted 50.44 and 52.49% mortality, respectively.

Differences among treatments were also observed in speed of action within a month of storage period. The manifestation of the bioactivity of the tested botanicals and other products has been generally gradual. However, *Phytolacca dodecandra* (SP, *Lantana camara* (LP and SP), *Nerium oleander* (LP) and *pyrethrum* (FP) inflicted 15-80% mortality within seven days of exposure time (Table 2) while on the other hand *Eucalyptus globulus* (LP), *Datura stramonium* (LP), *Melia azederach* (LP), cow dung, *Phytolacca dodecandra* (LP) inflicted 15 to 34% mortality even 28 DAI. Mortality in wood ash treated grains started increasing onwards from 14 DAI. According to Williams et al. (1993), the speed of action of insecticidal plants might be a reflection of the rate at which the active ingredient is able to reach the site of action.

There were highly ($p<0.001$) significant differences among treatments in the number of weevil progeny emerged as well as in the percentage of seed germination (Table 3) within the four months of storage period.

Significantly lower number of progeny were recorded on grains treated with pirimiphos-methyl, mixed wood ash, and pyrethrum, all of which were significantly different from the remaining treatments and the control (Table 3). Grains treated with *Allium sativum* (UB) and *Eucalyptus globulus* (UL) gave 763 and 513 F_1 weevil progeny, respectively. Grains treated with *Phytolacca dodecandra* (SP and LP), Hot pepper (PP and UP), *Melia azederach* (LP), *Lantana camara* (LP), Hot pepper (PP and UP), *Melia azederach* (LP), *Lantana camara* (LP) and Datura stramonium (LP), chilli pepper (PP) and *Nerium oleander* (LP) gave progeny weevils ranging from 144 to 213. Progeny emergence on the remaining 16 treatments ranged from 228 to 339 and the differences among them were not significant.

The population build up (starting from F_1 generation) was significantly lower in grains treated with pyrethrum and mixed wood ash. This result confirms our previous report on the promising performance of wood ash. Similar results have also been reported by Dick (1988) and Kyamaywa (1990).

The present study indicated the bio-potential of some plants and other materials for the control of the maize weevil. Based on the increased percentage mortality and reduced progeny build up through time, pyrethrum (FP), mixed wood ash, *Phytolacca dodecandra* (SP), *Nerium oleander* (LP), *Datura stramonium*, *Phytolacca dodecandra* (LP) are recommended for further testing to evaluate their efficiency and efficacy.

Table 2. Effect of treatments on adult maize weevil mortality, means of 4 replications

Trt. no.[1]	Percent mortality at days after treatment				
	7	14	21	28	Mean total
1	80.02	2.21	1.54	3.91	87.38a
2	7.76	16.77	16.34	30.76	71.62ab
3	14.78	13.35	24.72	15.47	68.33ac
4	31.88	14.27	13.39	6.25	65.78a-d
5	0.00	15.72	17.78	24.24	60.73b-e
6	0.83	6.67	16.26	34.10	57.86b-f
7	2.35	16.03	2.51	31.60	52.49b-g
8	5.42	9.46	30.32	5.26	50.44b-g
9	8.18	14.90	9.12	15.47	47.66b-g
10	20.61	4.62	11.17	9.99	46.22b-g
11	17.14	14.66	8.12	9.19	44.12b-g
12	5.82	10.39	8.96	16.32	43.71b-g
13	10.69	13.04	6.25	11.37	43.24b-g
14	12.81	6.57	12.17	14.58	42.91b-g
15	9.01	4.48	6.25	11.79	42.66b-g
16	8.11	6.83	12.17	13.74	40.84b-g
17	9.17	5.83	7.50	15.33	38.33c-g
18	11.03	6.81	8.48	11.89	38.22c-g
19	4.95	4.09	4.84	21.99	35.88c-g
20	0.76	8.98	10.66	15.41	35.80d-g
21	1.57	3.25	12.88	16.76	34.49d-g
22	5.06	10.05	7.51	11.79	34.41d-g
23	1.62	4.51	14.62	12.69	33.44b-f
24	2.56	6.59	7.97	14.11	31.23e-g
25	4.79	5.89	12.20	8.34	31.23e-g
26	7.51	6.91	1.48	10.61	26.51f-g
27	3.39	4.23	6.07	10.24	23.93g
28	3.45	5.98	5.14	7.70	22.27g
29	35.03	22.30	5.82	8.50	71.65ab
30	3.96	5.57	17.34	4.01	30.88e-g
SE±	4.70	3.44	3.52	3.70	6.62
LSD	0.30	0.26	0.26	0.24	16.40
CV (%)[2]	60.28	50.78	50.78	35.05	20.65

[1] See table 1 for treatment description;
[2] Values are in arcsine scale.
Means followed by the same letter within a column are not significantly different (DMRT[$P < 0.0001$]).
Percentage mortality values were subjected to angular transformation before analysis.

Table 3. The effect of different treatments on progeny emergence and germination of sorghum seeds. (Values are mean of four observation).

Trt. No.	Progeny emerged No.	Seed germination (%)
1	15.25 d	92.00 a, b
2	5.50 d	92.50 a
3	144.50 c	88.00 a-d
4	273.00 b-c	87.75 a-e
5	213.75 c	87.50 a-e
6	177.50 c	86.50 a-e
7	334.00 b-c	84.75 a-f
8	270.00 b-c	88.50 a-d
9	241.25 b-c	87.25 a-e
10	269.75 b-c	79.00 c-f
11	211.00 c	89.00 a-d
12	301.50 b-c	85.00 a-f
13	185.75 c	84.75 a-f
14	513.00 a-b	78.75 d-f
15	283.50 b-c	90.50 a-d
16	199.25c	83.25 a-f
17	183.75 c	86.75 a-e
18	339.00 b-c	75.25 e-f
19	226.75 c	82.75 a-f
20	289.00 b-c	83.75 a-f
21	215.00	91.50 a-c
22	289.00 b-c	86.75 a-e
23	312.00 b-c	83.50 a-f
24	317.00 b-c	91.50 a c
25	228.00 b-c	82.50 a-f
26	299.50 b-c	87.50 a-e
27	763.00 a	73.25 f
28	337.50 b-c	79.50 b-f
29	2.50 d	89.75 a-d
30	251.00 b-c	89.25 a-d
SE (±)	59.23	2.8
CV (±)[2]	24.03	6.54

[1] Means followed by the same letter within a column are not significantly different (DMRT [$p<0.0001$]).
[2] percent seed germination and progeny emergence are arcsine and square-root transformed values, respectively

It may be pointed out that low level of control exerted by most plant products may not be the true reflection of the bio-active potentials of the plants as a whole. All plant products were not prepared at the same time. Some of them were prepared long before they were used and had to be stored until all of the test materials were made ready. This may be one of the reasons why most of the plant products showed low level of efficacy than expected. Furthermore, the present work did not permit recording of chronic effects on developmental and reproductive physiology of the insect. Extracts of *A. indica* and many other plants are known to exert multiple acute and chronic effects such as growth regulatory, anti feedants, etc. on the same or different insects (Schmutterer et. al., 1980). Therefore, attention should be given in the future to investigate the bio-potential of these plants as well as other traditional materials used to combat pests in stores.

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Suppressing Effect of Different Botanicals on the Adzuki Bean Beetle (*Callosobruchus chinensis* L.)

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Abstract

Seven different plant species with known biocidal effect had been evaluated for two years in Holetta Research Center using incubator to find alternatives for primiphos methyl 2%. All the botanicals were used as powders except neem and "birbira" which were also used by either extracting the oil out of their seeds. The products were used at the rate of 50 mg, 100 mg, and 150 mg/ml per 100 gm of faba bean seed. Botanical treated seeds plus Pirimiphos-methyl treated and traditional checks were put in small ventilated cages into which were added five pairs of newly emerged adults of the insect per cage. All the cages were then put in the incubator replicated thrice. Data were collected on number of eggs laid fifteen days after emergence, adults emerged (live and dead), seeds clean, with egg and seeds with hole. The data were analyzed using Mstat statistical package by transforming the count data into $\log_{10}(n+1)$. The results showed that neem and birbira oil and pyrethrum flower powder gave best control of the beetle with log transformed value for the total number of eggs laid at the lowest rate of the three botanicals being 0.30, 0.30 and 0.21 respectively. However, none of the laid eggs survived. For the kernel oils, the minimum rates were even found too much requiring the study on lower rates than 0.5 gm/100 seed.

Introduction

Faba bean (*Vicia faba* L.), grown in the warmer areas of the country is attacked by the Adzuki bean beetle mainly in the stores. From a survey made in Yerer and Kereyu, it was confirmed that infestation becomes obvious with abundant laying of eggs about three months after storage. In this place, the percent weight reduction recorded due to the beetle ranged from 0% to 97% with a mean of 41% after seven months of storage (1,2). Different management methods have been tried to minimize the beetle damage. The best effective method against the beetle after one year verification had been the use of pirimiphos-methyl 2% Dust at the rate of 40 gm per quintal of seed(3). However, it is neither easily available nor affordable by the subsistent farmers. Therefore, looking for local substitutes such as the use of botanicals such as neem (*Azadirachta indica*) for the management of insect pests is an already established fact. Besides neem, there are others which have known biocidal effect and grow in our country. Therefore, testing of these botanicals for their efficacy against the Adzuki bean beetle was considered important.

Materials and Methods

Powdered forms of the seeds and leaves of Nech Bahirzaf (*Eucalyptus globulus* Labill.), seeds of Birbira (*Milletia ferruginea* (Hochst) Bak.), pepper tree (*Schinus molle Linneaus*), endod (*Phytolacca dodecandra* L'Her.), neem (*Azadirachta indica*), kosso (*Hagenia abyssinica* (Bruce) J.F. Gowelin) and pyrethrum flowers and also the oil from Birbira and neem were prepared. The oil of both botanicals were prepared by either extraction method.

Each botanical had been considered at a time with three rates: 50 mg, 100 mg and 150 mg for treating a 100 gram of faba bean seed with two checks pirimiphos-methyl 2% dust treated and untreated check which is the traditional check. The cultivar Kuse had been used at the rate of 100 gram per cage. The cages were ventilated at one end. One botanical powder was measured and put in cages and mixed with the seed and then, five male and five virgin female bruchids were put per cage. Each rate had been replicated three times. The treatments and the two checks were put in an incubator whose internal temperature had been adjusted to 28°C and about 50% internal relative humidity which had been created by putting open glass containers containing cold frozen water. The water had been replaced every morning and afternoon. Data were taken on the initial total number of eggs laid after fifteen days to incubation, number of live and dead bruchids emerged, number of seeds clean, with egg and with hole after thirty five days to incubation. The daily internal temperature and relative humidity had been recorded every morning and afternoon. The eight botanical had been tested. Birbira and neem seed were evaluated in the first year in powder form and in the second year in the oil form. The collected data were analyzed for each botanical over the two years.

Results and Discussion

E. globulus did not prevent egg laying both as seed and leaf powder. But, in the leaf powder treated cages, the live bruchids count though low, was significantly different form the standard check, but the number of clean seeds was not significant for all the treatments, however, in the standard check most of the eggs did not hatch. The seed powder did not prevent egg laying and emergence of adult from the laid eggs, but, it killed most of the emerged adults at the two higher rates asserting the existence of some level of biocidal effect (Table 1).

In *S. molle* treated seeds more eggs were laid and more number of live adult bruchids were obtained at the end of the experimental period which shows that the seed power of this botanical has no biocidal effect on the Adzuki bean beetle (Table 2). The same was true for the botanical *H. abyssinica* and *P. dodecandra* which were not effective when their seed powder were used to treat faba bean seeds i.e. the results obtained using these products were not better than the traditional check (Table 3 & 4). Whereas pyrethrum flower powder effectively controlled the Adzuki bean beetle even better than the standard check Pirimiphos-methyl 2% Dust at the recommended rate. The pyrethrum flower powder prevented egg laying and the small number of eggs laid did not develop into adult. In the second rate used there were few adults emerged, but found dead at the end of the experimental period (Table 5).

A. indica and *M. ferruginea* in the first year were evaluated as seed powder, but, both failed to prevent egg laying and like the seed powder of the *E. globulus*, the emerged adult bruchids most were found dead in the cages treated by both products. Particularly in the A. indica treated cages, the number of live bruchids counted was very low. Both of these botanicals have known higher biocidal effect for instance, M. ferruginea is locally known for mass harvesting fishes from river waters. The insecticidal effect of A. indica is a common knowledge. By these considerations, both botanicals were evaluated by extracting their kernel oil. Both gave comparable results with pyrethrum flower powder (Table 6 & 7). One possible explanation for the failure of these two botanicals when used in powder form was that due to the high oil content they have, the seed powders were making pellets while shaked to addmix them with the faba bean seeds which might have reduced effective contact between the insect and the botanical.

The result of 1993 study on crop comparative effect of the botanicals indicated that pyrethrum flower powder at all the rates was by far the most effective product (Table 8). On the other hand, pyrethrum flower powder, kernel oils of *A. indica* and *M. ferruginea* showed comparable effects on the beetle at all the rates tested in 1994 crop season. In both years, the difference among the botanicals was highly significant. In 1993 botanical rate interaction was significant for the live and dead bruchids counted.

From this experiment, therefore, it can be concluded that pyrethrum flower powder, oil from *A. indica* and *M. ferruginea* even at reduced rates than tested could control the Adzuki bean beetle. But, further study is required to identify the most effective lower rate, effect of the botanicals on the germination of treated seeds and safety period for consumption of treated seeds.

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5	1.10	0.00	0.71	2.42	1.22	0.64
Traditional Check	2.20	1.33	1.59	0.45	2.36	1.79
CV%	9.9	24.3	18.7	42.3	12.7	19.4
Lsd(0.05)	0.32	0.45	0.45	0.86	0.46	0.51

	[illegible]	[illegible]	[illegible]	[illegible]	2.32	1.82
M. ferruginea	2.12	0.64	1.70	0.29	2.34	1.80
CV (%)	12.5	28.4	20.8	48.9	10.9	17.8.
LSD (0.05)	0.46	0.60	0.38	0.75	0.36	0.469

Table 1. Effects of leaf and seed powders of *Eucalyptus globulus* on Adzuki bean beetle

Botanical	Rate (mg/100 g seed)	Initial eggs laid	Thirty Five Days After				
			Live bruchids	Dead bruchids	Seeds		
					Clean	with egg	with hole
E.globulus Leaf powder							

Table 5. Effects of leaf and seed powders of *Pyrethrum flower powder on C. chinensis*

	Rate	Initial	Thirty five days after

Botanical Insecticides to Control Stored Grain Insects with Special Reference to Weevils (*Sitophilus* spp.) on Maize

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Abstract

Laboratory studies on botanical insecticides for the control of maize grain weevils (*Sitophilus* spp), under no-choice condition were carried out at Jima Research Centre from 1992 to 1994. The result showed significant differences among the treatments when an adult mortality, progeny emergence, development period, are considered. The botanical ('gimi') *Chenopodium ambrosiodes* L. at 2% and 4% w/w powder was the most effective and gave comparable result to the synthetic insecticide primiphos-methyl (2% dust) in controlling the pest. Other botanical Mursine african L. ('Ketchema') and *Embelia schimperi* vatke, ('Enkoko') were also resulted in reasonable protection of maize grain from weevils in the seven month periods. However, because of the superior performance of *C. ambrosioides* it can be considered as a good source of botanical insecticide to protect stored maize for resource poor farmers in Ethiopia.

Introduction

The negative impacts of the past agricultural development practices in the world provoked the current call for sustainable agriculture, organic farming, polyculture and alternative agriculture systems [3, 10]. All such systems advocate an adequate food production through avoidance or limited use of synthetic fertilizers and pesticides, thereby make farmers less dependent on external inputs and to create safe environment. In these context, the use of biological and bio-pesticidal pest control methods are widely recommended (3, 5, 6, 10]. Botanical insecticides, plant derived pesticides, are an age-old practice of farmers, particularly in the tropics where synthetic insecticides are not readily available [7]. The resurgence of such approaches, especially crude-extracts, has become vital components of crop protection in developing nations.

About 2000 species of plants are known to have insecticidal, repellent, antifidant, or growth inhibiting effects on pests [3, 5, 7, 13]. Among the most widely noted bio-degradable organic insecticides used by farmers are those that belongs to plant species such as *Azadirachta*, *Derris*, *Eucalyptus*, *Tagetes*, *Capsicum*, *Nicotinin*, and *lanthana*, [5, 6, 7, 10].

Some investigations made in Ethiopia showed that botanical insecticides that originate from neem (*Azadiracta indica*) effectively controlled the maize weevil and bean bruchid

(1,2). The pepper tree (*Schinus molle*) also has a detrimental effect on house fly and bean bruchid. The weevils (*Sitophilus* spp.) and the grain moth (*Sitotroga cereallela*) are major insect pests of stored maize. Crop losses recorded due to these pests are 16.4% at Bako [1], 16.1% at Awassa [2] and up to 17.3% in the Keffa and Illubabor regions [9] indicating that an enormous quantity and quality of food is being lost annually.

The objective of this study was, therefore to determine the efficacy of some local botanicals for the control of storage pests with an ultimate goal of developing effective, safe and cheap storage insect pests management system.

Materials and Methods

Study on the efficacy of nine botanicals against weevils on maize was carried out under no-choice condition in laboratory at Jima Research Centre during 1993-1994 season. Based on preliminary observation made in 1992-1993 season, nine botanicals were selected for their insecticidal activities (Table 1). Seed, leaf, rhizome and bulb of these plants were collected, crushed, air dried, grounded and applied as dusts (Table 1).

Two set of trials with the nine botanicals at two rates (2% and 4% w/w. of synthetic insecticide, primiphos-methyl (7 ppm) and untreated (check) were compared for the period of seven months. Two hundred grains disinfested maize grain (variety UCB) were kept in a one litre glass jars. The botanicals and primiphos-methyl powders were mixed with the grain in each glass jar. After treatment, thirty adult (ten days old) weevils were introduced into each jar. The jars were incubated at room temperature (23°C) in a randomized design with three replications. Pesticide efficacy indices were determined for specific periods after the application of the treatments for each set of trials. Adult weevil mortality, F_1 progeny adult counts, development period of medium population, percent grain damage, weight loss and percent seed germination were the parameters recorded.

List of botanical treatments screened for control of Sitophilus weevils on stored maize

Code	Local Name	Species Name	Plant parts (Dust)
BI286	Garlic	Allium sativum	Bulb
BI386	'Kachama'	Mursine africana	Leaf
B1486	Chillies	Capsicum spp.	Fruit
B1586	'Kalawa'	Maesa lanceolata	Seed
B1686	'Gimi'	Chenopodium ambrosioides	Leaf, inflorescence
B1786	'Enkoko'	Embelia schimperi	Seed
B1886	Vetivar	Vetiveria zizanioides	Rhizome
B1986	'Damae'	Schrebera alata	Leaf
BI1086	'Siglu'	Exebergia spp.	Leaf

Count and percent data were transformed to square root (x+0.5) and arcsine, respectively. Susceptibility index was calculated according to dobie (1974). The data collected were subjected to analysis of variance.

Results and Discussion

Among the nine selected botanicals, the plant with code no. BI686 (*Chenopodium ambrosioides* L., locally known as 'gimi') was significantly superior than in untreated and other botanicals at both 2% and 4% levels (Table 1). It had comparable effect to the synthetic insecticide (*primiphos-methyl*) in controlling the pest.

· The other two botanicals, B1386, (*Mursine africana* L.), and B1786, (*Embelia schimperi* vatke), were also effective in controlling the weevil infestation and associated damage to the crop, although not as effective as BI686 and primiphos methyl. The remaining botanicals, except B1486 (*Capsicum* spp.), were only better than the untreated check. The botanical BI686 caused 100% adult mortality (Table 1). None of progeny survived in this treatment and grain susceptibility index was zero (Table 2). The damaged grains and associated weight loss was nil in this treatment (Table 3). Maize treated with BI686 and synthetic insecticide showed more than 95% seed germination compared with untreated check (7.3%) after seven month feeding of Sitophilus spp. (Table 3).

An over-all test of efficacy between 2% and 4% w/w has shown that an adult weevil death, susceptibility index and seed germination had higher effects (P=0.05) to increased concentration while F_1 progeny and kernel damaged (P=0.05), and grain weight loss (P=0.01) showed reduced effects on the pest. This indicates that higher dosage is more efficient in the management of pests.

In summary, B1386 (*M. africana*) and BI786 (*E. schimperi*) which may Ethiopian farmers use as antihelmetic, had a partial control of the pest infestation, which might be due to their antifidant peculiarities. An increased dosage of some of tested botanicals showed significant impacts to serve as protectant.

BI1686 (*C. ambrosioides*) seems very promising particularly in storage application. Most botanicals, even the popular neem are required at higher dosage than the standard rates 5% suggested for storage pest management [6].

C. ambosioides is a herbaceous aromatic plant, usually considered as a weed and distributed in the central highland of Ethiopia and in the Southern and Western regions [11]. The leaf of the plant is edible and the seed is used as source of various antihelmentic medicines, essential oils and condiments in the north and Central America [14] In Ethiopia, (C.ambrosioides, is locally available weed but its potentials as a botanical insect pest control such as weevils have been demonstrated in this experiment.

Further Research efforts are needed to determine the application dosage, the active phytochemicals and the real impacts in pest complex of larger store house and in farmer's storage conditions. The effect of mixtures of various botanicals (BI686, BI386, BI786)) should also be investigated that the product may be more efficiently utilized in pest management approaches.

Table 1. Efficacy of botanical dusts on Sitophilus weevil infestation on maize grain in the laboratory

Treatment Code	Mean number of dead adult weevils			
	7 DAT	15 DAT	21 DAT	28 DAT
BI286	3.1 (2.3)	4.3 (3.7)	9.0 (4.3)	11.3 (5.3)
B1386	2.3 (0.7)	4.3 (1.0)	10.3 (2.7)	11.7 (3.0)
BI486	2.0 (1.3)	5.0 (3.7)	7.7 (5.3)	9.7 (7.2)
B1586	0.0 (0.0)	0.7 (0.7)	3.3 (6.7)	6.0 (9.3)
BI686	30.0 (30.0)	30.0 (30.0)	30.0 (30.0)	30.0 (30.0)
BI786	4.7 (2.7)	9.0 (7.7)	12.7 (17.0)	19.3 (24.7)
BI886	5.3 (1.7)	11.7 (3.7)	11.7 (5.3)	17.0 (6.7)
BI986	1.3 (1.0)	4.0 (3.0)	4.3 (3.3)	5.0 (3.4)
BI1086	0.7 (0.0)	1.0 (1.0)	3.0 (9.0)	5.0 (11.0)
Actellic 2% (7 ppm)	30.0	30.0	30.0	30.0
Untreated check	0.7	0.7	8.3	9.7
LSD	0.99 (0.56)	1.22 (0.65)	1.4 (0.21)	0.66 (0.71)
C.V. (%)	26.4 (16.8)	19.8 (16.7)	24.7 (12.5)	19.3 (21.2)

DAT, Days after treatments applied.

Results indicated without parenthesis refer 4% and in parenthesis 2% w/w level respectively.

Table 2. Emergence of F_1 progeny, median development period and susceptibility index of maize treated with botanical dusts to protect from weevils (Sitophilus spp.) infestation, Melko.

Treatment Code	Mean F_1 Progeny Count	Average MDP	Mean SI (%)[1]
BI286	102.3 (128.7)	78.0 (57.3)	5.9 (8.5)
BI386	94.0 (143.0)	78.0 (60.0)	5.8 (8.3)
BI486	144.7 (155.7)	65.3 (60.0)	7.6 (8.4)
BI586	88.7 (96.0)	68.0 (60.0)	6.6 (7.6)
BI686	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
BI786	90.7 (112.0)	78.0 (60.0)	5.8 (7.9)
BI886	103.3 (105.0)	78.0 (57.3)	6.0 (8.1)
BI986	103.3 (156.3)	78.0 (60.0)	6.0 (8.4)
BI1086	135.0 (146.0)	78.0 (60.0)	6.3 (8.3)
Actellic 2% (7ppm)	0.0	0.0	0.0
Untreated check	251.3	60.0	9.2
LSD 0.05	4.5 (4.3)	7.2 (3.4)	1.2 (0.97)
CV(%)	20.2 (24.1)	6.6 (4.1)	11.8 (12.1)

Results indicated without parenthesis refer at 4% and in parenthesis 2% w/w level, respectively.

Susceptibility index (SI) = ($\frac{\ln F_1}{MDP}$) 100, where F_1 = total counts of F_1 progeny and MDP = median 50% population development period.

Table 3. Effects of botanical dusts on sitophilus weevils feeding damage, weight loss and maize seed germination in the laboratory

Treatment Code	Mean grain damage (%)			Mean weight loss (%)			Mean seed germination (%) (7 MAT)
	3 MAT	5 MAT	7 MAT	3 MAT	5 MAT	7 MAT	
BI286	26.3(42.0)	46.0(69.7)	64.0(80.3)	6.2(7.5)	7.6(16.9)	18.7(22.7)	36.0
BI386	18.0(32.0)	20.0(46.0)	27.7(55.3)	1.4(6.2)	1.6(7.2)	4.0(14.3)	68.7
BI486	30.0(36.7)	65.7(81.0)	80.3(86.7)	7.1(8.8)	22.3(24.3)	27.8(34.2)	12.7
BI586	16.3(29.3)	32.0(51.7)	42.3(60.7)	2.8(5.4)	5.9(6.9)	7.5(15.7)	53.3
BI686	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	95.7
BI786	13.3(8.3)	16.0(20.3)	21.0(23.0)	1.8(2.1)	2.7(2.7)	4.0(3.9)	83.7
BI886	15.7(30.0	29.7(29.0)	42.7(32.3)	2.6(5.7)	3.6(8.1)	12.1(5.3)	56.7
BI986	16.0(30.0)	25.3(45.0)	47.3(59.3)	2.0(5.8)	2.6(7.0)	15.6(16.7)	53.0
BI1086	20.3(29.0	26.3(43.7)	30.7(61.7)	4.0(5.2)	4.7(5.7)	8.2(19.5)	70.3
Actellic 2% (7PPM)	0.0	0.0	0.0	0.0	0.0	0.0	98.3
Untreated check	41.3	76.7	96.7	10.6	18.7	31.6	7.3
LSD 0.05	15.1(20.7)	20.3(20.5)	15.3(27.2)	2.2(2.3)	9.5(11.6)	9.8(12.7)	17.1
CV(%)	17.4(15.6)	39.6(31.7)	19.8(18.5)	19.1(18.9)	22.7(19.5)	20.1(19.0)	20.0

MAT, Month after treatments applied

Results indicated without parenthesis refer to 4% and with parenthesis 2% w/w level, respectively..

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PLANT PATHOLOGY

A Badna Virus in Ensete

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Abstract

Ensete seedlings which showed small chlorotic spots at their early growth stage later developed either deep yellowish stripe or streak symptoms. Such ensete leaves yielded the bacilliform particles with immunosorbent electron microscopy technique using diluted IgG to BSV. All ensete leaf samples collected from the major growing areas reacted positively with BSV IgG. They did not react with Cucumber Mosaic Virus (CMV) IgG. Indicator plants did not show any symptom after inoculation with ensete leaf sap preparations.

Purification methods developed for banana streak virus (BSV) and rice tungro bacilliform virus (RBTV) did not work for ensete leaf virus. The disease was found to be propagated vegetatively. This disease is widely distributed in all the major growing areas in Ethiopia and named ensete stripe disease. The associated bacilliform virus is referred to as ensete stripe virus (ESV).

Introduction

Ensete (*Ensete ventricosum*) is intensively grown in the south, southwest and central highlands of Ethiopia. It is a staple food crop for 10-15 million people in these densely populated areas of the country. This species is classified with banana. During disease surveys made in 1991, ensete plants with chlorotic leaf stripe and streak symptoms were observed for the first time in the Areka Experimental Station, Wolayita. Infected plants were found stunted.

The disease starts as small chlorotic spots on young seedlings and later develops either to deep yellowish stripe or streak. Such severely infected leaves become necrotic, shredded apart and finally appear as naked petioles. Follow-up surveys in 1992 and 1993 indicated the wide spread of this disease in all the major growing areas. Hence, the need to properly identify the causal agent of this disease is felt.

Materials and Methods

Virus source

Infected leaf samples with severe stripes and streaks were collected from the major ensete growing areas following the major all weather road route. Leaf samples were collected from Gurage, Kembata and Hadiya, Wolayita, Awasa, Hagereselam and Dilla areas. Leaf samples from infected plants were dried on Ca Cl_2. These samples and fresh leaves were brought to the department of Virology, Wageningen Agricultural University. When possible the leaf material was stored at 4-10°C during their transport from Ethiopia to Wageningen.

Serology

Dot blot immunoassay was performed using leaf sap from infected and healthy plants by grinding leaves in phosphate buffer saline (PBS) with 0.5ml between 20 per litre. Dilution of each sample (1:100) was made using the same buffer. Healthy banana leaf was used as a control. To overcome the pseudo-positive result (purplish color) from the healthy control, acetone powder was prepared and used (1% acetone powder in PHS-T (10ml) to which 10nl of crude BSV antiserum was added on a shaker for one hour) to remove antibodies to healthy substances with the method of Sambrook et al. (1989). Three microlitres of each sample was put on the nitrocellulose membrane, air dried and blocked with defatted milk powder (ELK) solution (5% ELK, 2% sucrose in PBS-T) for 30 minutes. After discarding the blocking solution, the membrane was incubated with:

- filtrate from one gram healthy cowpea leaf in 9 ml PBS-T to which $20\mu\ell$ of crude CMV antiserum was added on a shaker for 30 minutes.

- filtrate from 1% acetone powder in PBS-T (10ml) and $10\mu\ell$ crude BSV antiserum for a period of one hour

After discarding the filtrate, the nitrocellulose membrane was washed with PBS-T by putting on the rocking machine for 10 minutes (3x) to remove excess globulins. Then the membrane was incubated for a period of 30-60 minutes with 9 ml PBS-T and 3 nl goat antirabbit antiserum on shaker. After this the membrane was washed (3x) with AP 9.5 for 5 min. interval in each washing. Finally 5 ml of AP 9.5 was poured on the membrane with 22 ul NBT & 16.7 nl BCIP and put on a shaker till color development. The reaction was stopped by rinsing the membrane with demineralized water and then blot dried.

Local lesion assay test

Inoculum was prepared by grinding leaf samples showing typical chlorotic stripe and streak symptoms in cold 1% K_2HPO_4 with pH 7.2. Carborandum powder was dusted on the abaxial surface of the top leaves of the indicator plants (Chenopodium/amaranticolor; C. quinoa; Nicotiana benthemiana; N. oxidentalis; and Gomphrena globosa). Leaves were rubbed gently with the indicator finger after dipping in the viral suspension and then washed gently with some water to remove excess carborandum powder from the leaves. Plants were kept in green house for an observation period of one month.

Virus purification

The method of Lockhart (1986) and that of Omura et al. (1983) with some modifications for purifying the ensete virus were used. BSV antiserum was used in immuno dot blotting technique for extracts at each stage of the process. The procedure finally adopted was to mince infected ensete leaf samples and the extract the tissue 1:2 (W:V) in a blender with cold 0.05M Tris -citrate, pH 7.4, containing 0.5% (W:V) Na_2SO_3, 1%(W:V) Triton X-100 and 0.001M.EDTA.

Sodium sulphite and EDTA were added to Tris just before use. The homogenate was squeezed through double layer of cheese cloth and clarified by blending for 20 sec. With 25% (V:V) chloroform followed by low speed centrifugation (10000 rpm for 10 minutes in a Sorvall, GSA rotor). The aqueous supernatant phase was collected and the virus concentrated by ultracentrifugation at 38,000 rpm for one hour in Ti 45 rotor at 4°C.

The high speed pellets were resuspended in 0.01M phosphate buffer (PB), pH 7.2, and clarified using low speed and high speed centrifugation as done above. This was followed by resuspending of the pellets in 0.01M PB and then put under low speed centrifugation and loaded the supernatant in 0.40% CsC1 gradient in 20% (W;V) sucrose in PBST (Gumpf et al. 1981). Sample tubes were put on Sw-41 rotor and further purified by centrifugation for 4.5 hours at 38,000 rpm at 4°C. The suspected virus band (bluish in color) was removed with a pasteur pipet and dialyzed against 0.01M PB, pH 7.2, to remove the cesium salt. The identity of the virus particles and the purity of the final preparation were verified by serology, spectrophotometry and electron microscopy.

Electron microscopy

Leaf dip preparations were made by fixation of the preparations using glutaraldehyde. Leaves with virus symptoms were chopped using sharp edged blades on clean glass slides with three drops of water and glutaraldehyde separately. Sap was removed and put on carbon coated grids for three minutes and washed gently with two drops of demineralized water, blot dried and treated with a drop of PTA for 15-30 seconds. In the immuno sorbent electron microscopy (ISEM) method, diluted BSV antiserum (1:1000) was made using 0.05M PB and 20 nl of antiserum was placed on the surface of parafilm. Copper grids (carbon coated) were floated on drops of diluted antiserum using fine forceps and incubated for [illegible] min. at 37°C in incubator. The grids were then gently washed with two drops of 0.05M< PB, blot dried and transferred on the sap suspension from infected leaves. The grids were incubated for 20 hours at 4°C in cold room on the surface of sample suspension. The plates were properly sealed using parafilm to avoid evaporation.

Results

Disease occurrence and symptomatology

Ensete leaf virus disease with chlorotic leaf stripe and streak symptoms were found in all the major growing areas. Symptom of ensete chlorotic leaf stripe was observed on the whole leaf blade starting from the edge of the midrib and on the other hand, the severe streaking symptom of ensete make the whole leaf blade translucent. The symptoms of ensete chlorotic streak superficially resemble with that of banana mosaic caused by CMV infection. At the advanced stage, the chlorotic streaks become necrotic and the whole leaf blade shreds apart. Finally a naked petiole will be exposed.

Serology

All ensete leaf samples did not give any reaction with the antiserum of the three CMV strains (CMV-K8, CMV-S4, CMV-SL) in the dot blot immuno assay. Whereas, all samples (Batch I and II) were positive to the two strains of BSV (Ma and Rw). All samples developed the typical purplish color which indicates the presence of the badna virus antigens in the leaves.

Local lesion assay test

Five indicator test plant species, susceptible to CMV, did not develop any symptom after inoculations with ensete leaf sap suspensions. Extracts from these plants failed to react with CMV as well as with BSV antiserum.

Virus purification

Though the light bluish colored (bands) were seen under the UV light in the purified samples, it was not pure viral suspension when checked with spectrophotometer. At the same time, the same sample did not yield the bacilliform particles under the Electron Microscope (EM) though it was positive to BSV IgG in dot blot immunoassay.

Electron microscopy

Very few bacilliform particles were trapped from the crude sap of diseased seedlings grown in the green house after using the ISEM technique. Particles were not seen in leaf dip preparations, glutaraldehyde fixed sample and purified preparations even after using ISEM technique.

Discussion

Few bacilliform particles were detected from crude sap of ensete seedlings. These particles were similar in morphology with that of banana streak virus. In repeated dot blot immunoassays, all ensete samples reacted positively with BSV IgG while did not react with CMV. The positive reaction was detected for both the chlorotic stripe and streak showing leaves. The healthy banana leaf sample did not react with the above antiserums. Hence, the ensete leaf samples contained the badna virus antigens. The ensete leaf virus disease could clearly be distinguished from CMV infection of banana as the after show mosaic symptom on the midrib and serologically by antiserum. No other virus like particles were observed in either the crude or purified preparations of the diseased leaves of ensete and the current evidence at least suggests that the bacilliform virus is the causal agent for the disease. Since two symptoms were exhibited by this virus on the leaf, we prefer to name it as Ensete Stripe Virus (ESV). Failure of symptom development on the local lesion assay hosts could also indicate the need to look for other indicator plants for this particular virus.

The failure to trap many particles of the ensete leaf virus on antiserum coated grids could also support the view that badna viruses occur in low concentrations in their host tissue (Lockhart and Olszewski,). The positive reaction of all ensete samples to BSV IgG could also force us to reassess the farming system of ensete culture since sugarcane, which is a host of the badna virus (ScBV) is the major intercrop and the virus it harbors has the capability of infecting several different genera and families of plant species (Lockhart and Olszwski,). At the same time, the relationship of the various badna viruses of banana, sugercane, commelina, taro and other flora in the ensete culture should be studied properly to clearly understand the epidemiology of the ensete virus.

The stunting and shredding effects of the ensete virus was seen as detrimental to the production system of the crop thereby reducing the yield. Hence, we feel this virus to be of significant economic importance in the agricultural system of Ethiopia. ESV then appears to belong to BADNA group of viruses that include Aucuba ringspot, Banana streak, Cacao swollen shoot, Canna yellow mottle, Kalanchoe top-spotting, Rice tungro bacilliform and Sugarcane bacilliform (Brunt et al. 1990) viruses among others. Apart from the positive dot blot immuno assays and similarity of particle morphology with BSV there is no other data to support the relationships among these viruses of the same group. Further studies on purification, transmission and characterization are needed.

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Tuber Yield Loss Assessment of Potato Cultivars with Different Levels of Resistance to Late Blight

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Abstract

Potato yield loss assessment trial due to late light (LB) was conducted at the Holetta Research Centre in 1993 and 1994 seasons using cultivars possessing different level of reaction to the disease. The results revealed that, tuber yield loss due to LB were 67.1 and 45.5 percent with AUDPC 1483.8 and 1353.6 in 1993 and 1994 seasons, respectively, on a susceptible variety AL-624. In contrast, the percentage yield loss of cultivar. K-59A (26) that has field resistance were 14,6 and 2.7 percent during the respective testing seasons. Across all cultivars, yield loss due to LB averaged 35 and 27 percent in respective years. The combined percentage reduction of total tuber yield between controlled and uncontrolled treatments was significant during both seasons. There were strong negative correlation between total tuber yield and LB incidence (r = -0.84 in 1993, r = -0.60 in 1994), tuber quality and LB severity (r = -0.74 in 1993, r = -0.57 in 1994). The actual losses in tuber yield and quality caused by late blight necessitate the control of the disease in areas prevalence. However, the low level disease on the resistant clones may make chemical control effective at reduced applications if at all necessary.

Introduction

Late blight of potato, caused by Phytophthora infestans (Mont) de Bary, is a prevalent disease in all potato (*Solanum tuberosum* L.) production areas of Ethiopia. The severity of the disease depends on the susceptibility of cultivars and on the weather conditions. The disease is catastrophic in many partes of the country especially in areas where potato is cultivated from June to September (1). Because of LB, potato cultivation has been declined in most areas where the crop used to be produced in large acreage. The growing of susceptible varieties relatively in large areas coupled with the unavailability of effective control measures has given *P. infestans* an opportunity to develop without hinderance. Thus, the disease become a permanent threat in potato production in the main rain season.

Field resistance in potato varieties to LB and the associated losses in tuber yield were demonstrated earlier (2, 5). Moreover, strong association has been found between level of severity and subsequent loss of tuber yield (3, 4).

Amongst various control measures, to date, fungicides are the most indispensable approach to control the disease. However, the existence of variations among cultivars in response to the disease greatly improve the need in frequency of fungicide application. As a result, the fungicide application programs are entirely dependent on level of epidemics of the disease (3). Thus this experiment was executed to investigate the loss incurred due to LB in potato cultivars which have different level of resistance and, hence, yield potential.

Materials and Methods

Six-cultivars, namely, K-59A(26), CIP-378367.4, Sissay, Awash (CIP-378501.3), UK-80-3, and AL - 624, were used in the experiments done in 1993 and 1994 seasons at Holetta Research Centre. The first two cultivars are resistant, while the next three are moderately resistant and the last one is highly susceptible. Treatments were arranged in factorial experiment in randomized complete block design with three replications. Each cultivar was planted in 0.3 by 0.7 m spacing on 3.6 by 3.0 m plot. Complete protection of late blight was achieved by applying the fungicide Redomil MZ 63.5% WP at a rate of 3 kg ha^{-1} at weekly interval starting with the first disease appearance. To reduce spray drift between sprayed and un sprayed plots, buffer zones were created by planting three rows of oats between plots. Fertilizer was applied in rows at planting at a rate of 300 kg ha^{-1} diammonium phosphate.

The disease severity was estimated by taking the percent leaf tissue affected at weekly interval starting from the first appearance of the symptoms. Six to seven such ratings were taken during the seasons. Area under disease progress curve (AUDPC) was calculated from the percentage leaf area affected. All plots were harvested at about 120 days after planting.

Results and Discussion

In the 1993 season the fungicide considerably controlled late blight for much of the growing season. However, other diseases such as viruses appeared on both treated and untreated plots. No attempt was made to control these other diseases.

The yield loss due to LB was greatest (67.1%) and the AUDPC was also highest (1483.8) in the susceptible variety AL - 624 (Table 1). In contrast, both the percentage yield loss and AUDPC were the smallest for the cultivar K-59A (26) that possesses field resistance. Yield loss due to LB averaged 35.1% across all cultivars.

The percentage reduction of tuber yield between treated and untreated treatments was found to be highly significant ($P < 0.01$). Negative correlation was obtained between total tuber yield and LB incidence ($r = -0.78$) and between marketable yield and LB was $r = -0.74$ indicating that there is a strong negative relationship between LB and tuber yield of potato.

In the 1994 season the disease incidence and tuber yield loss were the same as the preceding crop season (Table 2). Tuber yield and yield components of potato were influenced by late blight incidence. The late blight incidence expressed by AUDPC on the susceptible variety Al-624 was significantly higher than the late blight incidence on resistant cultivar k-9A (26). Yield losses ranged from 2.7 to 45.5%. As to the preceding experimental year, the highest yield loss (45.5%) and late blight incidence, (AUDPC 1458) was obtained on the susceptible cultivar AL-624. On the other hand, the lowest tuber yield loss (2.7%) and the lowest AUDPC (370) was recorded on the resistant cultivar K-59A (26). The mean yield loss of 25.6% was obtained during the season.

Again in 1994, the percentage reduction in tuber yield and late blight severity between protected and unprotected treatments were found to be significant ($P < 0.01$). Negative correlation was obtained between tuber yield per hill and late blight severity, ($r = -0.51$), between marketable yield and late blight severity, ($r = -0.57$), and total tuber yield and late blight severity, ($r = -0.60$), indicating that there is a negative relationship between the disease and tuber yield of potato.

The two years results indicated that the association of field resistance to late blight was strong. The susceptible cultivar AL-624 and similar other cultivars need complete protection against the disease in areas like Holetta where the disease is prevalent. Whereas cultivars such as CIP-378501.3, Sissay, and UK-80.3 seems to be dependant on the epidemic level of the disease. Hence, these and other similar cultivars may or may not need chemical protection. Cultivars such as K-59A (26) does not necessitate chemical protection.

Generally, the losses in tuber yield and quality caused by late blight on susceptible cultivars can be reduced using fungicide where the disease is prevalent. Whereas the low level of late blight incidence in the resistant and moderately resistant cultivars however may make chemical control at a lower frequencies more effective.

The results and the conclusion given above lacks informations on economics part which, therefore, needs further investigation on this line.

Table 1. Yield loss of different cultivars due to late blight at Holetta in 1993

Treatment	Uncontrolled (t/ha)		Controlled (t/ha)		% yield reduction
	AUDPC	Yield	AUDPC	Yield	
K-59A(26)	366.23C	16.6AB	10.38	19.5C	14.6
CIP-378501.3	717.16B	20.4A	19.78	31.9A	36.1
CIP-378367.4	417.07C	16.8AB	39.05	27.0AB	37.8
Sissay	622.45BC	16.2AB	10.68	25.9B	37.6
Uk-80-3	405.51C	23.5A	29.82	28.4AB	17.3
AL-624	1483.78A	9.7B	32.26	29.5AB	67.1
Mean					35.1
CV%		33.37		11.23	
SE +		1.053		0.559	

Table 2. Yield loss of different cultivars due to late blight at Holetta in 1994

Treatment	Uncontrolled		Controlled		Percent yield reduction
	AUDPC	Yield (t/ha)	AUDPC	Yield (t/ha)	
K-59A(26)	369.86	24.9A	76.82	25.6AB	2.7
CIP-378501.3	1186.86	18.9AB	77.06	20.1B	5.9
CIP-378367.4	1201.36	13.9B	176.28	26.5A	47.5
Sissay	1276.74	14.3B	195.07	18.4C	22.3
Uk-80-3	635.96	17.8AB	201.89	25.2AB	29.4
AL-624	1353.63	10.9C	169.05	20.08BC	45.6
Mean					25.6
CV%	11	27	52	26	
SE +	62.89	1.558	17.36	1.879	

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Recent Out Breaks of Turcicum Leaf Blight on Maize in Ethiopia

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Abstract

Turcicum leaf blight incited by *Exserohilum turcicum* (Pass.) Leonard and Suggs (Syn. Helminthosporium turcicum Pass.) occurs in humid areas of the world. In Ethiopia the prevalence of the disease was first reported in early 1950s. Although it was said to be one of the major maize diseases, its effect was considered as minor and sporadic. However, recently it is being causing extensive damage in high and mid altitudes. In some places like Bilito. Upper Birr and Ayehu state farms total crop failures were reported. In Bure/Illubabor and Gedo/west Shoa serious infections before flowering were observed.

Moreover, reports in the country indicate that there is a wide range of variabilities (cultural. morphological and pathogenic) among different isolates of the pathogenic fungus. And a loss figure of up to 49.8% was recorded from a susceptible variety under high disease pressure.

Introduction

The importance of maize is increasing extremely in wide areas in Ethiopia for its high productivity and low cost requirement. However, diseases contribute substantially to low yield. Currently, out of the many diseases identified on maize, turcicum leaf blight (TLB) caused by Exserohilum turcicum (Pass.) Leonard and Suggs. is the principal disease problem on maize (2).

Although the disease was reported to occur as early as the 1950s, there was no much attention given because local and East African maize varieties were found to be tolerant to major diseases of maize, like turcicum leaf blight and common rust caused by Puccinia sorghi Schw. Because of the increasing need of maize production use of improved and disease free seed is indispensable. Serious outbreaks of TLB reported in major maize producing areas. For instance, at Bilito, Birr and Ayehu state farms total crop failures were reported in 1994 crop season (personal observations). Besides, surveys in the last two years indicated that TLB to be widely distributed and abundantly prevalent in wetter humid medium altitude to highland areas where the bulk of maize is produced.

In some areas like Gedo/Western Shoa and Bure/Illubabor, severe infections were observed before the crop flowers. The disease was found to attack maize as low as 500m in the Gambella plain and as high as 2800 m in the Bale highlands. However, the effects are more pronounced in areas where there is extended rainfall, warmer temperature and higher humidity. In the field. TLB often appears to be a disease of late growth stages, which may be closely associated with inoculum buildup.

Epidemiology

Infection of *E. turcicum* is influenced by high and extended dew period, warm temperature, dense inoculum concentration and favorable plant age (Levy and Cohn, 1983). Excessive thick sowing and dense weed population also increase its effect (Pelmus *et al.* 1986). Several days rainfall and dew hasten mass outbreak of the disease (Markov, 1969).

A monoculture of maize with an abundance of crop residues from one season to the next may maintain large quantities of initial inoculum (Boosalis *et al.* 1967). Delayed sowing, frequent rain, high humidity and heavy dew in warmer nights encourage fast development of the disease (Popov, 1968).

History

The presence of turcicum leaf blight in Ethiopia was first reported in 1952 in Keffa, Harrarghe, Shoa and Sidamo provinces by experts from Jima Agricultural School. Stewart and Dagnachew (1967) index as an important disease on maize. Kranz (1969) reported that the conidial state of Trichometasphaeria turcica (currently - Setosphaeria turcica) as a dangerous fungus to a number of maize varieties in Bako area. Mengistu et al (1980) consider TLB as economically important disease on maize and sorghum. Mengistu (1982) found that Arsi-Negelle and Alemaya to be sites for the development of the disease. A review by Teclemariam (1985) and a check list by Mengistu (1990) describe TLB as the second most important maize disease. Tewabech (1990) has shown its wider distribution in mid to highland areas where maize is extensively grown. Assefa and Tewabech (1993) in their review reported that TLB to be the number one disease problem on maize for its wider distribution, frequent infection and severe intensity throughout the country.

Survey

Survey was conducted in Southern, south western and Western Regions of Ethiopia to assess the prevalence of major maize diseases with due attention to the incidence and severities of turcicum leaf blight. Observations on TLB were made on 25 plants per field in each of 10 fields of specific locations. Localities and fields were selected randomly. Severe infections were recorded at Agaro Sobokaboshe, Awasa College and IAR fields, Tuka, Medfegna and Bedele Zuria localities.

Incidence of the disease was very high in most of the areas surveyed. Unfortunately the intensity of the disease was found to be higher in areas where maize is staple food and widely cultivated.

Studies on TLB in Ethiopia

Some studies on TLB (Assefa, 1994) showed the following results:

- There was a range of variability (cultural, morphological and pathogenic) among the different isolates of *E. turcicum* collected from major maize growing regions of Ethiopia.
- Yield loss of 49.8% was estimated on a susceptible variety under high disease pressure (created by artificial inoculation).
- The relationship between weather and disease variables was found to depend upon the type of maize variety although disease development was observed to depend on different weather factors.
- Epidemics of TLB around Bako starts from third week of July to second week of September. Some infections were also observed during the off-seasons near river banks and bottom-lands.

Perspectives

In the future prevailing physiological races of this pathogen should be identified in order to determine the distribution and type of races in the country. In addition to the different cultural control measures recommended so far, varietal screening and/or development of resistant varieties through breeding may be given due attention.

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Pathogenic Variation of *Exserohilum turcicum* Isolates on Maize (*Zea mays*) Variety Beletech

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Abstract

A study, on 15 *Exserohilum turcicum* single conidial isolates for their abilities to produce leaf blight on maize variety Beletech, was conducted in field and greenhouse. The Experiment was designed in randomized complete block design with three replications.

Disease pressure was created by artificial inoculation twice in field and once in greenhouse. Lesion type, number and size were evaluated. However, the degree of virulence of each isolate was interpreted as a virulence rating factor (VRF) which was determined by multiplying the severity of virulence (percentage disease incurred by a specific isolate) with the percentage of leaves infected.

Results indicated that there was a significant ($P=0.015$) difference among *E. turcicum* isolates tested in virulence rating. Isolates that were collected from Gedo (West Shoa) and Awassa (Sidamo) had the highest mean virulence rating (MVR) of 256.2 and 253, respectively whereas the lowest MVR (113) was recorded from an isolate obtained at Shambu (Eastern Wollega). Correlation analysis showed that MVR was highly ($P\leq0.003$) correlated with mean lesion number and lesion type. MVR was significantly correlated with spore length and rate of germination. Almost all isolates required relatively fewer days (2-7) to initiate lesions on maize variety Beletech. However, this varies from isolate to isolate. Thus, isolates 2, 9 and 15 required fewer (3) days while isolates 3 and 4 need a mean of 6 days for lesion formation.

Introduction

Turcicum leaf blight (TLB) caused by *Exserohilum turcicum* (Pass.) Leonard and Suggs (Syn=*Helminthosporium turcicum* Pass.) *teliomorph Setosphaeria turcica* (Lutrell) produces cultural and pathogenic variations (Robert, 1952; Bergquist and Masias, 1974). Variation in aggressiveness of *E. turcicum* was observed by some isolates which cause severe TLB disease on a host genotype (Levy, 1989; Nelson et al, 1970). However, Jenkins et al (1957) reported higher variation in disease reaction of *E. turcicum* isolates as a result of variation in pathogenicity of the organism, the host plant and the environment. Robels (1949) found differences in virulence of E. turcicum isolates on the same host attributed to variation in the fungus isolates related to specificity of hosts.

Pataky et al (1986) suggest that epidemic development of TLB depends on the ability of the fungus to infect, grow and reproduce on maize and the ability of the conidia to disperse within the crop and subsequently cause infection. Eventhough TLB is the principal maize disease in Ethiopia there was no information on pathogenic variations of the pathogenic fungus. Therefore, this study was carried out to determine whether *E. turcicum* isolates differ in their abilities to infect a common host maize variety Beletech.

Materials and Methods

Fifteen single conidial isolates of E. turcicum were used for the study. These were collected from naturally infected maize plants from 12 regions (15 locations) in Ethiopia where maize is widely grown. Single conidial isolation was made by first growing on moist chamber and picking singly with a sterile blood lancet using a dissecting microscope. The monospores were first raised on lactose casein hydrolysate agar medium (LCA) and maintained on 3.9% potato dextrose agar (PDA) slants preserved at 4°C until inoculation.

Inocula were obtained from tap water washing of 12 days incubated cultures on LCA at 25°C. The cultures were diluted to a spore concentration of 35 x 10^3 per milliliter of water for each inoculation, as determined from hemacytometer readings. Approximately 10ml of the inocula suspension was directed into the whorl of each plant with atomizers.

Field experiment

The experiment was designed in randomized complete block design with 3 replications. In the field each replication has two row plots 75 cm apart and 12 hill plants in 30cm distance from each other. Two inoculations, four days apart were made at five to six leaf stage of the plants. Field records were commenced 8 days after the first inoculation and continued every three days until 27 days after inoculation, up to which minimum variation was observed due to the blurring effect of high secondary infection. Lesion number, area (approximated from the measurement of lesion width and length), and lesion type (R+ with chlorotic lesion only, R chlorotic lesion with some necrosis, R-chlorotic lesion with considerable necrosis, S susceptible (necrotic or wilted)), number of leaves infected per plant, height the disease reached on the plant (from the record of the upper most leaf infected onto the plant), visual estimation of percent leaf area covered by the disease (percentage disease), and the severity in 1-6 scoring scale where 1-means no disease visualized and 6-wide bands of lesions coalescing at inoculation sites and with leaves dead or wilting by the disease (Robert, 1952). The degree of virulence of each isolate was interpreted as a virulence rating factor, which was determined by multiplying severity by percentage of leaves infected. Sporulation capacity was indexed with 0-4 Scale (0-no sporulation, 1 - spares, 2 - moderate, 3 - abundant and 4 - profuse sporulation) by taking diseased leaf samples at 10 to 12 leaf stage of the plant and incubate in the laboratory in a moist chamber and observe under dissecting microscope.

Greenhouse experiment

In greenhouse, plants were grown in plastic pots of 1.8 kg soil capacity on a mixture of sterile black:red:sand at 1:1:1 ratio. Each treatment was placed in a randomized complete block design with three replications. Two plant were raised on a pot. Inoculation was carried out with the same spore concentration as of the field study but only with one inoculation at 4-6 leaf stage of plants by spraying upto runoff. The night and day temperature of the greenhouse was in the range of 19 to 22°C and 23 to 25°C, respectively and the humidity was maintained at 75% to 86%. Evaluations were made twice 17 and 22 days after inoculation for lesion type and severity. Lesion length and number were recorded every other day after the first lesion was visualized.

Analysis of variance was made for every parameter and correlation coefficients and regression analysis were computed. Means were estimated by Duncan's multiple range test both at 5% and 1% level of significance.

Results and Discussion

Virulence rating

The highest mean virulence ratings of 256.2 were obtained from isolates at Gedo(Gd)/west Shoa and the lowest mean virulence rating of 113 was recorded from isolate Shambu(Sbw)/eastern Wollega (Table 1). The trend of virulence rating increment of isolates from Awasa and Uke (Uk)/eastern Wollega was consistently increasing at higher rate during the observation period (8-27) days after inoculation) whereas that of isolates from Sbw and Agarfa (Bag)/Bale was uniformly at lower rate. Mean virulence rating was highly ($P \leq 0.003$) correlated with mean lesion number ($r=0.733$) and lesion type in the field. It was significantly ($P<0.040$) correlated with spore length on LCA grown isolates ($r=0.558$) and spore germination on 3% water agar ($r=0.534$). But it was not related to rate of colony radial growth on LCA and most greenhouse susceptibility components. Isolates differ significant ($P=0.015$) in degree of virulence (Table 2). But they did not show much variations on the basis of lesion type (Table 1, Fig 2).

Lesion size

The highest lesion area of 3.85cm^2 was from isolate Borujawi (Arb)/Arsi and the narrowest area (1.59cm^2) was measured from isolate Sbw. Lesion area expansion every three days between 8-27 days, after inoculation, was continuously highest for isolate Uk whereas isolates Sbw, Assosa (As) and Guramba (GD)/Gondar were lower. Lesion area was significantly correlated with percentage germination on 3% water agar ($r=0.586$) and spore length on LCA ($r=0.510$). Significant differences were observed among isolates for lesion areas measured from the 11th to the 21st day after inoculation and for mean lesion area.

Table 1. Mean susceptibility components[a] of Fifteen E.turcicum isolates on maize variety, Beletech in the field.

Isolate	LT^{ns}	MVR	LNI^{ns}	SpC	MLN^{ns}	MLA	HLP^{ns}	Days to mea^{ns}	1^{st} lesion range
Al	3.33	197.43^{AB}	2.63	0.33^{B}	6.71	2.33^{BC}	9.67	4.33	(2-7)
ArB	3.33	204.90^{AB}	3.12	1.33^{AB}	8.29	3.85^{A}	10.00	3.00	(3-3)
As	3.67	199.60^{AB}	2.57	1.83AB	6 18	1.98^{BC}	8.33	6.00	(4.7)
Aw	3.33	253.05^{AB}	2.66	0.67^{B}	7.54	2.28^{BC}	9.55	5.67	(3-7)
Bag	3.00	170.60^{AB}	1.97	1.67^{AB}	4 18	2.19^{BC}	8.55	3.33	(3-4)
Bk	3.33	243.05^{A}	3.19	1.67^{AB}	5 77	1.90^{BC}	8.11	5.67	(3-7)
Gdw	3.67	256.19^{A}	2.94	0.83^{AB}	8.03	2.14^{BC}	10.11	3.67	(3-5)
GrB	3.00	159.95^{AB}	2.60	1.33^{AB}	4.50	3.10^{ABC}	10.44	4.33	(3-7)
Gjm	3.67	205.02^{AB}	2.40	2.67^{A}	7.60	3.44^{AB}	10.22	3.00	(3-3)
GD	3.67	198.74^{AB}	2.94	1.83^{AB}	5.69	2.24^{BC}	9.33	3.33	(3-4)
Jm	3.67	240.78^{A}	3.28	0.67^{B}	6.04	2.99^{ABC}	9.22	4.00	(3-7)
KB	3.00	223.21^{A}	2.63	2.00^{AB}	6.95	3.00^{ABC}	11.34	4.00	(2-7)
Sbw	2.67	113.02^{B}	1.79	0.33^{B}	2.99	1.59^{C}	9.66	4.33	(2-7)
Uk	3.67	242.76^{A}	3.28	2.00^{AB}	7.14	2.31^{BC}	10.33	4.00	(2-7)
Zw	3.00	136.73^{AB}	2.40	0.33^{B}	3.51	2.23^{BC}	10.11	3.00	(2-4)
Mean	3.33	203.00	2.69	1.30	6.07	2.50	9.67	4.11	
CV%	14.93	22.54	22.52	22 82	16.26	24.01	11.46	38.78	

a - mean of every three days record (from 8 to 27 days after inoculation)

LT-lesion type (1-chlorotic lesion without necrosis, 2 - chlorotic lesion with some necrosis, 3 - chlorotic lesion with considerable necrosis, 4 - wilted and necrotic lesions without chlorosis) MVR - Mean virulence rating.

SpC - sporulation capacity (0 - 4 index where 0 is no sporulation and 4 is abundantly sporulating), LNI - no. of leaves infected/plant MLN -mean lesion number, MLA - mean lesion area

Values followed by same letter are not significantly different at 1% probability in DMRT (duncans multiple range test), ns - there was no significant difference for the variable.

Table 2. Degree of virulence of isolates

	Source			
	Replication	Isolate	Error	Total
DF	2	14	28	44
MS LT	0.20^{ns}	0.33^{ns}	0.25	
MS MVR	58590.18^{**}	5457.86^{**}	2099.94	
MS LNI	0.18^{ns}	0.60^{ns}	0.37	
MS SpC	1.28^{**}	0.24^{**}	0.08	
MS MLN	1.72^{**}	0.29^{ns}	0.15	
MS MLA	0.39^{ns}	1.18^{**}	0.36	
MS HLRP	22.76^{**}	2.23^{ns}	1.23	
MS MDFL	19.76^{**}	2.98^{ns}	2.54	

MS- mean square, * - significant at 5%, ** - significant at 1% or above
DF - degrees of freedom, MS - mean virulence rating,
SpC- sporulation capacity, LT - lesion type, MLN - mean lesion number,
MLA - mean lesion area, HLRP - Height lesion reached on the plant,
MDFL - mean days to first lesion initiation

Lesion number

Variation in lesion number was observed only for 20 days after inoculation. Isolates Gdw, Arb and Kellala and Bero (KB)/eastern Wollega had the highest numbers of lesions 12.7, 8.80 and 8.76, respectively and isolates from Ziwai (ZW)/southern Shoa and Sbw had the lowest number of lesions per plant, 3.40 and 4.50 at 20 days after inoculation (Data not tabulated). However, isolates did not show significant differences from each other in mean lesion number. Uniformly higher number of lesions were formed by isolate Uk and lower number by isolate Sbw. Mean lesion number was significantly correlated with spore length on LCA ($r = 0.601$) and spore germination on 3% water agar ($r = 0.532$). The long conidia and fast germinating types would be normal wild-type as observed in planta (Dr. Gunter Welz, Personal Communication) and, therefore, could be more infectious than short and slow germinating ones which may be considered as off-types.

Sporulation capacity

An isolate from Mereawi (Gjm)/Gojam showed highest sporulation capability of 2.67 whereas the lowest (0.33) being from isolates Alemaya (Al)/Harerghe and Sbw. A highly significant (P = 0.007) negative correlation (r = -0.666) was found between sporulation capacity of isolates in the field and rate of growth on LCA. Statistically highly significant (P = 0.008) differences was observed among isolates in sporulation capacity.

Disease progress

Progress of isolate KB was observed to reach the most upper part (11.34th leaves) of the plant which was similar to the field reaction observed during sample collection. The lowest progress recorded (8.11th leaves) was from isolate Bako(Bk)/west Shoa. The number of days to first lesion formation was in the range of 2-7 days after inoculation. This suggests that almost all isolates required fewer days to initiate lesions on Beletech. However, this varies from isolate to isolate. Thus, three days were enough to initiate lesion by isolates Arb, Gjm and Zw, while isolates As and Aw required a mean of 6 days. Isolates were not variable in type of lesion, daily lesion expansion and first lesion initiation on Beletech both in field and greenhouse.

The work of Lim et al (1974) and Leonard (1988) were confirmed in this experiment in that virulence of isolates in the field and severity in greenhouse were not correlated to in vitro rate of growth. Isolates with high frequency of lesion were found to have highest capacity for virulence. The results obtained in this study show that isolates collected from different regions/localities differed significantly in their pathogenic potential on a common host, maize variety Beletech, in four features: sporulation capacity, virulence rating, lesion area and features: sporulation capacity, virulence rating, lesion area and lesion number record 20 days after inoculation. This agrees with the report of Robert (1952) that states monoconidial isolates of E. turcicum from maize differed from each other and varied in their ability to infect a common host. The wide range of variability in pathogenicity could partly be due to variation in the fungus isolates as related to specificity to the host substantiating the idea of Robert and Sprague (1960) and also to environmental and geographic factors where isolates were collected. There were also variations among the isolates both in greenhouse and field.

Field severity was statistically significant for 17 to 24 days after inoculation. Best variations in virulence rating was visualized from 17 to 20 days. But incidence was significant only at 17 days after inoculation. Good variations in the greenhouse were observed for lesion number counts the first and third day and sporulation capacity (Table 3).

For the fungus *E. turcicum* is variable pathogenically and the same morphologically, breeders can effectively develop resistant varieties against turcicum leaf blight in Ethiopia. The variable response of maize variety Beletech indicated that the variety may have tolerance and could be selected for resistance against the disease.

Table 3. Relation of *E.turcicum* Isolates to susceptibility components on maize variety Beletech in greenhouse studies

Isolate	DfLF	LL1	LL2	LL3	LL4	LL5	LN1	LN2	LN3	LN4	LN5	LT	SPC	VE
A1	10.00	1.93	2.14	2.46	3.33	4.40	1.67	2.33	3.00	3.00	3.00	1.33	2.83	8.33
Arb	10.00	1.90	2.90	3.40	4.17	5.37	1.67	2.67	4.00	5.00	7.00	1.67	2.33	34.00
As	10.00	2.10	2.70	3.13	4.23	5.20	1.67	1.67	2.33	2.33	2.33	1.33	1.17	6.67
Aw	16.67	2.67	3.80	5.10	6.07	6.60	2.67	4.33	4.33	5.00	5.00	1.67	1.50	14.00
Bag	10.33	3.67	4.43	4.77	5.00	5.10	1.67	2.67	4.00	5.00	5.33	1.33	3.17	26.33
Bk	14.33	2.77	3.43	4.40	5.20	7.00	2.67	4.00	5.67	7.33	10.33	2.00	3.33	52.00
Gdw	9.67	3.67	5.50	6.50	7.47	8.83	2.33	3.67	5.00	5.33	7.00	1.67	2.50	32.33
Grb	11.33	2.87	3.30	3.63	4.60	5.63	3.67	4.33	6.00	6.00	6.33	2.00	4.00	27.00
Gjm	11.33	3.00	3.30	3.73	4.37	5.00	1.67	2.00	2.33	2.67	3.00	1.33	1.83	9.00
GD	17.33	4.53	5.33	7.13	8.90	9.83	2.00	2.33	4.00	5.00	5.67	1.67	0.67	32.67
Jm	16.00	1.10	1.86	3.29	3.85	4.50	1.33	2.00	2.00	3.00	3.00	1.00	0.67	13.67
KB	9.00	3.50	4.13	4.40	4.67	5.50	1.33	1.67	1.67	2.67	4.33	1.33	2.83	15.00
Sbw	12.33	0.67	0.93	1.07	1.2	1.43	0.33	0.33	0.33	0.33	0.33	0.33	0.00	2.00
Uk	16.33	2.63	3.23	4.07	4.80	5.43	1.33	2.67	3.67	5.00	5.33	1.33	1.00	17.67
Zw	14.67	1.97	2.60	3.57	4.00	4.27	1.67	2.00	3.00	3.00	3.67	1.33	3.00	11.33
	ns	ns	ns	ns	ns	ns	P=0.02	ns	P=0.04	ns	ns	ns	P=0.00	ns
							CV=51.80%		CV=55.79%			ns	49.06%	ns

DfLF - days to first lesion formation, LL - lesion length (cm), LN - lesion number LT - lesion types, SPS - sporulation capacity (1-4) index), VE - severity (0-100%); LLL-LL5 - daily measurement of lesion length from the first day to the fifth day and LN1-LN5 indicates lesion number count from day 1 to 5 after the first lesion was observed; SPC, LT and VE data are records of the 22 days after inoculation

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A Disease of Faba Bean Caused by *Fusarium avenaceum* (Corda ex Fr.) Sacc. [1]

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Abstract

A relatively new disease of faba bean (*Vicia faba* L.) has been studied for many years at Holetta Research Center. The disease attacked lower parts of the stem, causing foot rot. Obvious symptoms of the disease included wilting, premature death, and lodging. This disease was caused by *Fusarium avenaceum* (Corda ex Fr.) Sacc. and was found to be strongly pathogenic to faba bean.

Pathogenicity test revealed that among the eight crop plant species tested, only *Brassica napus* and *B. campestris* were immune to the faba bean isolate of *F. Avenaceum. Triticum aestivum, T. durum, Hordium valgar, Eragrostis tef, Guizotia abyssinica, Linum usitatisimum, Pisum sativum,* and *Vicia faba* were infected at various degree. Among the major weed species, *Spergula harvensis, Avena fatua, Guizotia scabra, Phalaris paradoxa, Polygonum nepalens,* and *Caylusea abyssinica*, were infected.

The disease caused a yield loss of 48.7% in faba bean; ranging from 34.6 to 91.7% depending on the disease intensity. Major effect of the disease was on pod setting, seed size, and weight. The disease caused premature death of the plant under severe cases. The seed from foot rot infected plant also affected stand establishment of the next crop when used as a seed source.

It was observed that the disease became more severe when August rainfall was above average and was extended to mid-October. It also seemed to occur more on acidic soils. This disease is increasingly being serious in some fields at Holetta. Precautions are essential to limit further spread of the disease.

Introduction

A disease of faba bean was first observed at Holetta Agricultural Research Center in 1973 on very few plants (Yitbarek, 1983). The disease was soon found to infect faba bean planted in other experimental sites such as Quiha in the north and Kokate in the south of the country. The disease was very severe in 1983, in some trial and production fields at Holetta

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Research Center, killing up to 90% of the plant populations (Yitbarek, 1983). Severe foot rot has also occurred in 1986, 1990, and 1993, in experimental plots at Holetta. In 1990, 15% foot rot disease has occurred in Farming Systems Research trials in farmer fields at Welmera, near Holetta.

This paper presents and discusses the results of some investigations made on the causal agent, its pathogenicity, host range, yield losses, and observations on the disease development in the different seasons.

Materials and Methods

Faba bean fields, mainly at Holetta, were assessed for the occurrence of stem infection and wilt for many years. Symptoms were described and the causal agent was identified at the plant pathology laboratory at Holetta. Conidia were measured and compared with the CMI description made for this fungus (CMI No. 25). Colony characteristics were studied on three media namely faba bean dextrose agar (FBDA), Potato dextrose agar (PDA) and Yeast extract agar (YEA).

Pathogenicity of the fungus was studied in a greenhouse by artificially inoculating faba bean plants (cultivar CS 20 DK). Inoculum suspension, containing conidia and mycelia, was placed on each stem of the test plant with the help of cotton and immediately covered with cellophane to reduce evaporation. The experiment was laid out in completely randomized design with ten replications. Infection and symptom development were recorded. Reisolation of the fungus was made for confirmation.

Host range of the pathogen was studied on eight crops and 17 weed species using artificial inoculation of potted plants in the greenhouse and naturally grown plants in the field. Inoculation method, experimental design and observations made were as described above.

Losses of faba bean yield due to this disease was assessed on an improved cultivar, CS 20 DK, in the 1993 cropping season at Holetta. Single tiller technique was used to generate this information (Dereje, 1993). Seed weight, pod and seed number were measured from plants with different levels of foot rot infection which was scored on 0 to 5 severity scoring scale (0 = no disease; 5 = most severe). Percent loss was calculated based on measurements made on healthy tillers. Six seed lots collected from plants with different degree of foot rot infection were studied for germination, emergence and seedling vigour in laboratory and in the greenhouse. Moreover, attempts were made to relate foot rot occurrence in the last ten years to weather conditions during the respective crop period.

Results and Discussion

Symptoms and disease development

Dark to brown, often elongated (0.5 x 2.5 cm), lesions appeared on the stems of faba bean at about the ground level in early to mid-September. As the season progressed the size of the lesions increased and destroyed the whole foot part of the plant (from ground level to about 30cm height). Eventually, an orange coloured fungal growth with white margins appeared on the center of the lesions and later developed on most parts of the lesions. The infection was always more severe on the stem, 5 to 25 cm above ground. The lesions spread along the stem with intermittent attenuation at about 5cm. The lesions do not circumscribe the stems and at least some parts of a stem remained without infection. However, infected plants were easily breakable at the infection site and hence lodged. The leaves were soon dead and the stems became dark or dark-brown. Most of severely infected plants were without pods.

Microscopic observation and culturing of the pathogen

Observations of the causal organism under microscope revealed that the orange fungal growth on the infected tissues (lesions) were fruiting bodies bearing conidia with 3 to 7 septation, and 10.8 to 67.2 u by 3.6 to 5.0 u length by width measurements. The abundant white mycelial growth on infected tissue resembled sporodochia bearing the orange conidia but did not from a true sporodochia. When this fungus was cultured on FBDA, PDA and YEA, at 20 to 24°C, faster growth and more abundant sporulation were observed only on PDA than on FBDA and YEA. Based on the microscopic features (mainly conidia size) and cultural characteristics, the causal fungus was identified as *Fusarium avenaceum* (Corda ex Fr) Sacc. and this was later confirmed by Common Wealth Mycological Institute (CMI # 241885).

Pathogenicity test

When inoculum, spore and mycelial suspension, was introduced on the basal portion of faba bean plants black lesions which resembled water-soaked tissue started to develop. Inoculated plants wilted within four days while the control plants remained healthy up to the end of the test. Culturing of the fungus from the wilted plants gave pure culture of *F. avenaceum* that was identical to the original culture.

Host range study

Among the field crops grown on infested soils with *F. Avenaceum* isolated from faba bean, *Triticum aestivum, T. durum, Hordium valgar, Eragrostis tef, Guizotia abyssinica, Linum usitatisimum, Pisum sativum*, and *Vicia faba* were infected. However, Brassica napus and B. campestris were immune. Natural infection occurred only in *Linum, Pisum* and *Vicia* species among the tested crops. Six weed species, namely Spergula harvensis, Avena fatua, Guizotia scabra, Phalaris paradoxa, Polygonum nepalens, and Caylusea abyssinica, were found infected at various degree and only *Spergula harvensis* was severely infected. Of all the plants tested, faba bean was the most severely infected species and infection of Eragrostis tef and Guizotia abyssinica by this pathogen was reported for the first time.

Table 1. Mean yield and yield component for foot rot rating scale in faba bean

Severity score	Yield/tiller (g)	100-seed weight (g)	Number		
			[illegible]/til	seeds/til	seeds/pod
0	15.9a	51.8ab	11.6a	31.3a	2.7a
1	10.4b	62.3a	7.5b	18.1b	2.7a
2	9.6b	50.9ab	7.1b	18.3b	2.5b
3	7.3bc	46.5b	5.9bc	15.6bc	2.6a
4	4.8c	44.9b	4.2c	10.7c	2.5a
5	1.3d	29.7c	1.2c	4.7d	2.3a

Values with the same letter in a column are not significantly different using duncan's Multiple Range Test ($p = 0.05$).

Yield loss studies

Seed yield per tiller decreased from 15.9 to 1.3 g when foot rot severity was increased from O to 5 rating scale (Table 1). A mean yield loss of 48.7% was calculated and the losses ranged from 34.6 to 91.7% depending on the severity foot rot. Among yield components, pods per tiller, seeds per tiller, and 100-seed weight were the most affected (Table 1). However, number of seeds per pod was not affected. Hence the effect of the foot rot was mainly due to pod set and seed size.

Regression of seed yield (dependent variable) on foot rot score (independent variable) gave a significant linear relationship ($R^2 = 95\%$ and $r = -0.98^{**}$). Similarly, percent yield loss (dependent variable) was regressed on foot rot severity score (independent variable) and produced a linear relationship which were highly significant (R^2 - 96% and $r = 0.98^{**}$), suggesting that root rot can cause considerable yield loss to faba bean production.

Effect of foot rot on subsequent faba bean crop

Germination percentage dropped from 97.2 to 77.4% due to severe infection of foot rot (Table 2). The effect was both on viability and vigor of the seed germination. Similarly, emergence was dropped from 95.0 to 47.0% in the very severely infected seed lot (Table 2). Seed emergence was significantly delayed only when the seed was highly affected (disease score = 5). However, plant height, fresh and dry weight of roots and shoots, and flowering of the emerged plants were not affected. These indicate that foot rot infection also affected the stand establishment of next crop planted from infected seed source.

Table 2. Germination and emergence of faba bean seeds collected from plants showing different degree of foot rot infection.

Score	Germination		Emergence	
	Percentage	Energy	Percentage	Period
0	97.2a	79.6b	95.0a	10.4a
1	97.8a	85.5a	85.0ab	11.4a
2	95.2ab	88.8a	85.0ab	11.0a
3	92.7b	75.8c	80.0b	10.4a
4	89.4c	75.2c	80.0b	10.1a
5	77.4d	64.8d	47.0c	14.8b

Values with the same letter in a column are not significantly different using Duncan's Multiple Range Test ($p = 0.05$).

Foot rot occurrence and some precautions to limit spread

Foot rot disease of faba bean is building up from season to season. In the last ten years, it has been observed to increase at Holetta Agricultural Research Center and very severe cases were reported in 1983, 1985, 1986, 1988, 1990, 1992, and 1993 cropping seasons (Dereje, 1994). Analysis of the weather data in relation to foot rot severity in these cropping seasons revealed that August rainfall was more than the average by about 14mm and was extended until October.

Unlike to black root rot caused by *F. Solani* which is dominant in vertisol (back clay soil) with relatively higher pH, foot rot seem to occur on nitosol (red clay soil) that is more acidic.

Faba bean on two production fields (Field-F13a and Field-G4) at Holetta Agricultural Research Center were severely damaged in the 1993 cropping season. Almost all plants (97.3%) were infected and about half (48.6%) of the plants in these fields were podless. The infection was associated with heavy sporulation of the fungus.

The dissemination the pathogen is mainly through crop residues during plowing, and infected seeds. *F. avenacum* sporulates heavily, and air borne spores could also be important means of disease spread. The pathogen having such versatile spread mechanisms, the necessary precautions must be taken inorder not to spread it to other production areas. Restrictive measures including burning of infected crop or crop residues that carry fungal inoculum; ploughing the field immediately after burning in order to destroy the remaining inocula on the soil surface; cleaning farm implements after plowing such infested fields and use of clean (healthy) seed source should be practiced. In general, control measures consisting of crop rotation with non host crops and sanitation with particular reference to destroying crop residues after harvest are advised. The fields should also be free of weeds that serve as host to the pathogen during the cropping and noncropping seasons.

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Studies on Fungal Diseases of Wheat at the Plant Protection Research Center, 1974–1994

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Abstract

Research on fungal diseases of wheat commenced in the then scientific Phytopathological Laboratory in 1974. The fungal diseases encountered in surveys included rusts, blotches, smuts, scab, powdery mildew, ergot and root rots. The most prevalent were rusts and septoria blotches. In many instances, epidemics of rusts were registered in Shoa, Arsi and Bale Regions, particularly, Arsi Negele, Debre Zeit and Herero were hot spot areas for at least two rust species. During this period, cultivars Mamba, Romany B.C., Gara, KKBB, Dashen and Enkoy lost resistance to one or more rust diseases. The 45.2% yield loss due to stem rust also confirmed the significance of rust diseases in the country. In more detailed studies, 36, 57 and 90 races of stem, (*Puccinia graminis*), leaf, (*P.recondita*) and yellow rust (*P. striformis*) respectively had been identified till 1988. The stem rust monogenic lines Sr22, Sr5 and Sr11; leaf rust lines Lr9 and Lr19 and Yr3/Yr5 and Yr10 possessed genes effective against the respective prevalent races for many years. Furthermore, wheat and wild grasses grown in the off-season were found to be sources of rust infection. Rust spores were also detected in the atmosphere almost all year round. The development of stem rust in tissues of susceptible variety was rather quick and there was no hypersensitivity reaction of the cells as in the resistant one. In other experiments, three methods of artificial inoculation and one method of drying and preserving stem rust spores were recommended. Local and exotic varieties/lines were screened under artificial and natural infections and at different growth stages resulting in identification of entries resistant to rust(s).

Introduction

Wheat is affected by numerous fungal, bacterial, viral and nematode diseases. The first report on fungal parasites and plant diseases occurring in Ethiopia was issued in 1937. Progress in studies and identification of pathogens was published in 1959. Later on, "index of plant diseases" and "plant diseases of economic importance" for Ethiopia were published (1).

A large number of important diseases of wheat and other crops have been identified and published after establishment of Debre-Zeit Experiment Station in 1953. Furthermore, a coordinated research on wheat and other crops started with the inception of Institute of

Agricultural Research (IAR) in 1966 at Holetta Research Station (1). In addition, the foundation of Scientific Phytopathological laboratory (SPL) at Ambo in 1977 had strengthened the crop protection research in the country. It has been conducting research on fungal, bacterial, viral and nematode diseases on cereals, pulses and vegetable crops. In particular, more pathological works on wheat rusts have been carried out as the pathogens and the crop are important for the country.

Therefore, this paper reviews the researches done on fungal diseases of wheat in Plant Protection Research Center from 1974 till 1994.

Disease Surveys

Surveys on fungal diseases have been carried out in the major wheat producing areas of Shoa, Arsi, Bale, Harer, Sidamo, Wollega and Gojam Regions for many years. The diseases encountered included rusts, blotches, smuts, scab, powdery mildew, ergot and root rots. The most important were rusts and blotches (6).

In the surveyed years, there was no wheat crop where rusts and/or blotches have not been recorded. Especially, the incidence and severity of the three rusts were high. Stem rust was widely distributed. Leaf rust was more in prevalence and severity and yellow rust was slight to moderate in most of the years, but maximum at higher altitudes (> 2400m.a.s.l.). Epidemics of the three rusts were registered and the frequencies were more in Shoa, Arsi and Bale regions. Epidemics of stem and leaf rust were higher in the former and leaf and stripe rust in the latter two regions. During these periods, many wheat varieties were severely infected and lost their resistance to the diseases (2,6,7,9-13).

Survey was also represented by the Ethiopian Wheat Rust Trap Nursery (EWRTN) conducted at different location (1850-2800 m) and regions of the country from 1980-1994.

According to 14 years data, less percentage of EWRTN entries were infected with stem rust at altitudes > 2225m. The percent of leaf rust infected entries was more or less similar at lower, mid and higher altitudes. Yellow rust was more prevalent at altitudes > 2100m. Hence, Arsi-Negele, Debre-Zeit and Ambo; Arsi-Negele, Debre-Zeit and Herero and Kulumsa, Herero and Dixis were hot spot areas for stem, leaf and yellow rusts, respectively. These places were recommended as screening sites for the respective rusts (7, 9-13).

Specialists from Shola laboratory and SPL surveyed cereal ergot in Arsi and Bale regions and found ergot sclerotium on one wheat plant at Dinsho in Bale region in 1979 (4).

In the same year, seeds of 12 bread and durum wheat varieties from Holetta, Ginchi and Ambo were analyzed. The highest Helminthosporium infected seeds were recorded at Ambo (39-60%) followed by Ginchi (27-50%) and Holetta (11-40%). The percent was higher on black soil (Ambo and Ginchi) than red soil (Holetta) (7).

In 1987, survey on root rot diseases indicated that the highest development was recorded at Dixis on variety Dashen (34%). But, the infection was lower where maize and rapeseed were preceeding crops. The infected sample was cultured and identified to be *Fusarium oxysporium* and *F. sambusianum* (2,7).

Loss Assessment

Yield loss due to stem rust of wheat was studied under artificial and natural infection during 1986-1987 seasons. Yield losses of a susceptible variety, Ambo local, with artificial inoculation averaged 52.2% while 45.2% under natural infection. Losses in kernel weight were 47 and 42,3% under artificial and natural stem rust infection, respectively (7).

Wheat Rust Races and Virulence Studies

Physiological races of wheat rusts and the reaction of the monogenic lines to the dominant races have been studied in SPL since 1974.

Stem Rust

Twenty four stem rust races were identified in 1973, of which, six races could not be recovered since then. From 1974-1988, 36 additional races were identified by the Center and a total of 60 races existed in the country till 1988. Among these, race 53, 117, 15, 189, 86, 924, 115, 42 and 40 were dominant. Apart from this, virulence studies of the dominant races on the stem rust monogenic lines exhibited that Sr genes 22, 5 and 11 were effective against race 53 for 6, 5 and 4 years out of 9 years, respectively, while Sr 5, 8 and 22 were resistant to race 117 for 4 to 5 years. From the dominant races, 8 of them were avirulent to Sr gene 22; 5 races to Sr 5; 4 races to Sr 11 and others. Sr 5, 8, 22. Tt-1 and etc were effective genes for the virulent races 117 and 189 (Table 1). These genes appeared to be possible sources of resistance for the disease (1,2,7,9).

Leaf Rust

Eight leaf rust races were identified, of which, 5 races were not registered again after 1970. From 1974-1988, 57 additional new races were identified by the Center and a total of 65 leaf rust races existed in the country. Out of these, race 61, 141, 25, 62, 1, 167, 6, 3, 5 and 40 were frequently met from the populations. Besides this, virulence studies were carried out on about 30 races from 1975 to 1986. The virulent races, 176 and 144, were tested on the monogenic lines and Lr gene 1 was found effective against the former race for two years, while Lr gene 1, 20 and 21 were resistant to the latter race only for one year. The monogenic lines 9 and 19 were resistant to race 2 and 62 for 5 and 4 years out of the 6, respectively. These genes were resistant to different prevalent races, but at lower frequency. Races 2, 62 and 61 were avirulent to Lr 1 for 4 years. Line 1, 2a and 3Ka were also unaffected by many races (Table 1). Therefore, these resistant genes can be used in the breeding program of wheat (1,2,7,9).

Table 1. Frequency of resistance of Sr and Lr monogenic lines to the dominant stem and leaf rust races in the test years.

Stem rust races	No. of years tested	Resistant Sr genes in years		Leaf rust races	No. of years tested	Resistant Lr genes in years	
		2	3			2	3
53	9	26, Tt-1, Tt-2	6,7a,8, 9,10,30. Gt	1	6	2b,3ka, 12,13,14, 17,24	2a
117	8	6,7b,9a 25,26- ,27, 30,Tt-3	-	62	5	1,3ka,9, 12,1,3, 14b,17, 19,24	-
15	6	5,8,11, 25,26, 2,7,29	22	3	5	-	3KA,9 19
189	4	Tt-1	-	6	4	-	-
42	3	5,6,8, 11,22	-	61	4	-	2A,9,19
115	2	22	-	53	4	-	-
86	2	22, 26, 30, Tt-1, Gt	-	58	3	-	-
294	2	5,6	-	123	3	-	-
89	2	22, 26, 30, Tt- 1 Gt	-	141	3	-	1,9,19
-	-	-	-	25	2	-	25

Yellow rust

A total of 90 races were reported till 1989 of which OEO, 2EO, OE2, and 6EO were the dominant ones. During 1982 and 1983 varieties possessing genes Yr3, Yr4, Yr5, and Yr10 were effective to the races identified in the respective years (1,2,7,9).

Wheat Disease Control

Cultural Control. Effect of planting dates on the development of stem rust on wheat was studied for three years at Ambo. The result revealed that June 1-15 were the ideal date to reduce the disease incidence and increase yield, while late plantings (July-August_ increased the disease and reduced the yields. Hence, June 1 planting gave 29.5 q/ha and later dates gave 24,9, 10.6, 2.1 and 2.8 q/ha. (7).

Chemical Control. The effect of chemicals in controlling leaf and stem rust on variety Boohai and septoria on variety Laketch were studied from 1985 to 1986 seasons. Seven treatments-Tilt 250 EC at 0.5 and 1.0 l/ha. Impact at 0.75 and 1.0 l/ha, Bayleton at 0.5 and 1.0 Kg/ha. at 2 sprayings each and untreated check were included. The mean severity of leaf rust, stem rust, septoria leaf and glume blotches were 88%, 68%, 9.0 and 5.0 scores, respectively. The most effective and profitable control were obtained by Tilt 250 EC at 0.5 l/ha. and impact at 1.0 l/ha. These fungicides were recommended to be used by farmers (7).

Host Resistance. From 1974-1994, indigenous and exotic bread, durum and other species of wheat were screened against rusts in the greenhouse or under field condition using artificial and/or natural rust infections at Ambo. A total of 15300 entries were tested for their resistance to the 3 rusts. The results revealed that 1366, 1889, 861 and 1201 materials were found to be resistant to stem, leaf, yellow and stem and leaf rusts, respectively. In most cases, the land races, durum wheat and *T. aethiopicum* were very susceptible to stem and leaf rust. Most bread wheat were resistant to them (1,7 10-13).

In EWRTN a total of 1146 entries were tested at different locations from 1980-1994. Of which, the status of widely cultivated bread and durum wheat varieties were studied. The bread wheat varieties Dereselign, K-6290 Bulk, K-6295-4A and Enkoy and the durum wheat varieties Boohai and Cocorit 71 were susceptible to stem rust. To the contrary, the bread wheat varieties Mamba, Dashen, Gara, Et-13 A2 and Batu were resistant throughout the test years. The above indicated stem rust susceptible bread wheat varieties were resistant to leaf rust, but they were infected up to 100S in the latter years. This was also true to the durum wheat variety Cocorit 71. Varieties Dashen, Gara and Batu were still resistant to leaf rust. Enkoy and Et-13 A2 were the only varieties that resisted yellow rust till recently. But, varieties Romany B.C., Mamba, Gara, Batu and KKBB, Dashen and others were severely infected by yellow rust in the nursery (7,9,11-13).

Basic Studies

Sources of Cereal Rust Infection. Study on sources of cereal rust spores was done in the dry season of 1976-77. Observations between December, 1976 and February, 1977 confirmed the development of rust on wheat and barley in Nekemte. In this period, farmers were preparing wheat fields for planting. At Ginchi wheat was at milky and dough stages too. At Sheno and Debre-Birhan, wheat and barley crops were at all stages of growth in February, 1977. Therefore, main reservoirs of rust were wheat and barley grown in the highlands of Ethiopia during the dry seas[illegible] Wild grasses are also another reservoir for stem rust (7).

Influence of Altitude. The influence of altitude on the development of rust diseases was studied on 32 durum and bread wheat varieties planted at different agro-climatic zones from 1980-83. The highest stem rust infection was recorded at altitudes 1600 to 25[illegible]m, leaf rust 1850-2600m and yellow rust from 2150-2850 m (7).

Methods of Artificial Inoculation with Stem Rust. Five methods of inoculation of wheat with stem rust were studied at Ambo. Optimum results were obtained by spraying plants with spore suspension or dusting with spore-talc mixture followed by covering the plants with plastic sheet for 12 hrs. at night. In-addition, inoculation with spore suspension by hypodermic syringe in the leaf sheaths appeared to be lower as compared to the treatments covered with plastic sheet. But, it gave guaranteed infection under all weather conditions and it was promising when the inoculum was less and have very susceptible variety. The above 2 methods, without covering with plastic were effective only during the main and small rainy seasons. Thus, the 3 methods were recommended for screening of varieties at different periods of the seasons at Ambo (1,7,8).

Methods of Drying and Preserving Stem Rust Spores. Seven methods of drying and preserving stem rust urediospores were studied at Ambo in 1985-1987. The viability of spores was 71%. After one month of storage, the germination in all the methods was 56.4 to 63.7% except the control which was 25.5%. There was no significant difference among them except the control. After 6, 12, 18 and 24 months of storage the viability of spores decreased to 22.9; 20.7; 5.4 and 1.1 percent, respectively. In the 6 and 12 months of preservations, 22.9 and 20.7 of viable spores were obtained in treatments when spores dried at room temperature for 48 hrs compared to 15.0 and 14.8% germination when spores were dried in desiccator with Cacl2 for 48 hrs., sealed and stored at 4.5oC, respectively. Therefore, the former method was by far better than the others because at least 1.1% viable spores can be obtained after 24 months, whereas, none in the others (5,7).

Intermediate Host and Host Range. To determine the role of infected *Berberis holstii* with acidial stage of rust, 28 wheat, oat, barley and rye varieties were inoculated with aeciospores in 1978. But, no symptom of infection appeared on the crops. Host range study done between 1985-1987 revealed that wheat seedlings were infected with stem rust collected from wild grasses- *Lolium multiflorium*, *Hordium* sp. and *setaria* sp. Inoculum collected from wheat has also infected seedlings of Lolium spp. (7).

Histological Study. Histological feature of stem rust development in susceptible and resistant varieties was studied in 1987/88 crop season. The fungus developmental process in tissues of susceptible variety was rather quick. In 24 hrs, after inoculation of seedlings with spores, infectious hypha appeared. On 2nd and 3rd day, a developed mycelium spreaded between parenchymal cells and around the vascular bundles as well as haustoria were found in some cells. On the 8th day, at the places of congestion of mycelium, the formation of urediospores under epidermal cells was observed. As zone of defence, cells were strongly discolored around the fungus in the resistant variety. The more cells got into contact with hypha of the fungus, the more clearly the hypersensitivity reaction was observed (7).

Atmospheric Sporé Load of Wheat Rust at Ambo

Atmospheric spore load of wheat stem, leaf and Yellow rusts was recorded from July, 1990 to September, 1991 using wooden spore trap on which vaseline smeared microscopic slides were placed in the north, south, east and west directions. With the exception of July, 1990, stem and leaf rust spores were present through out the year and in all directions. Yellow rust was caught for 9 months except February, March and April. In many instances, the spore catch was greater in the direction of wind movement. Furthermore, an increased spore concentration was observed during warmer months for stem and leaf rust and during cooler months of the year for yellow rust. The period of first spore appearance in the atmosphere and initial infection on the host plants were more or less similar too (3,10).

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Occurrence of Rust and Reaction of Barley Varieties/Landraces

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Abstract

The three rust diseases, leaf rust (*Puccinia hordei*), stem rust (*P. graminis*) and stripe rust (P. striiformis) are reported to affect barley in Ethiopia. But, their distribution severity and level of resistance on barley varieties and land races cultivated in the major barley growing regions have not been monitored. Hence, non-replicated nursery consisting of 150 barley entries including a susceptible check was planted and evaluated at Ambo, Holetta, Adet, Sheno and Sinana for 2-4 years. Low level of stem rust infection was observed once on some entries at Ambo, stripe rust was recorded only on Ardu-12-60B food barley and PGRC/E accession at Sheno and Ambo. Leaf rust, however, was severe and widely distributed on the nursery at many of the locations and years. Ambo, Adet and Sinana were used as screening sites since they were hot spot areas for leaf rust. The intensity of leaf rust was high, but there was no shift in resistance on widely cultivated varieties, PGRC/E accessions and differential varieties. Malting and food barley varieties Proctor, Holkr, Ardu 12 60B and HB 100; accession numbers 202551-202553, 202603 and 202654 and the differential cultivars Oderbrucker and Quinn remained resistant across locations and years. The variable response of leaf rust differentials as well as the resistance of two varieties across locations and years might indicate the unchanged heterogenisity of the pathogen. On the other hand, 13 leaf rust susceptible land races, with high yielding capacity as compared to the local check, were promoted to a tolerance study. Such cultivars will give reasonable yields in the years of leaf rust epidemics.

Introduction

Barley is widely threatened by many economically important diseases. Rusts (*Puccinia spp.*), Scald (*Rhynchosporium Secalis*) and blotches (*Helminthosporium spp.*) are among the major yield limiting fungal diseases (Dickson, 1956; Bekele 1985).

Three rust diseases/leaf rust (*Puccinia hordei*), Stem rust (*P. graminis*) and Stripe rust (*P. striiformis*) are reported to affect the yield of barley (2,9,10). (Dickson, 1956; Stepanov, 1975). Barley leaf rust is the most widely distributed in the mediterranean countries and causes serious yield losses in Northern Africa and Pakistan. In Soviet union it causes 3-7% yield losses at epidemic if infection starts at early crop stages (6,10,11) (Peresipkin, 1979; Trofimouskaya, 1972).

Barley stem rust may be caused by a number of barley specific races of either Puccinia graminis f.sp. tritici (wheat stem rust) or *P. graminis* f.sp. *secalis* (rye stem rust). Though stem rust is present throughout the humid and sub-humid areas of the world, it is not of major importance to barley as they tend to escape severe losses by maturing early (Peresipkin, 1979; Stepanov, 1975.

Stripe rust caused by *puccinia striiformis* f.sp. hordei is of particular importance in some countries of Europe, Asia, America, India, Pakistan, Nepal, Afghanistan and the higher elevation of the Arabian peninsula. It produces symptoms and effects similar to that of wheat stripe rust (Peresipkin, 1979; Stepanov, 1975.

Preliminary studies, revealed leaf rust to be the most widely distributed in all barley growing high lands of Ethiopia. Survey conducted in 1986/87 crop season indicated high incidence and severity between 80 and 100% at heading-dough stages in many production fields of Arsi, Bale, Wollega and some parts of Shewa regions. The disease causes a yield loss of 14%. However, stem and yellow rust were slight in the regions (IAR, 1972 and SPL, 1986/87).

Therefore, the objectives of the experiment were to study the occurrence of the three rust diseases and monitor the level of resistance or susceptibility of barley varieties and lines at different locations.

Materials and Methods

A total of 150 entries including 9 widely cultivated food malting barley varieties, 125 PGRC/E accessions, 9 barley leaf rust differentials, a standard and 6 local susceptible checks were planted at Ambo, Holetta, Sheno (Shewa), Adet (Gojam) and Sinana (Bale region) during 1989, 1992-1994 crop seasons.

The nursery was non-replicated with a single row of 2.5 m and 0.2 m between rows but at Ambo each entry was planted in double row of 2.5 m by 0.4 m and replicated two times. Susceptible local checks were planted at intervals of 20 test lines and around the nursery. Disease evaluation was done once between September to October. Rust diseases were recorded by using the Loegering scale (%) and other foliar diseases, the Saari and Prescott, 0-9 scale. Average Coefficient of Infection (ACI) was used to select and rank resistant entries to leaf rust. The response of the varieties had constant values i.e. resistant (R) - 0.2, moderately resistant (MR) - 0.4, moderately susceptible (MS) - 0.8 and susceptible (S) - 1.0. These values were multiplied with the severities across location, added and divided by the number of locations to get the mean ACI score of each year and variety. Varieties and accessions with an ACI up to 5 score were considered resistant (1,10). Weather data like rainfall, temperature and relative humidity were collected.

Results and Discussion

The mean percentage of leaf rust infected entries were 90, 98, 98, 40 and 84% at Ambo, Adet, Sinana, Holetta and Sheno, respectively. The number of infected entries tend to reduce above 2460 m.a.s.l (Holetta and Sheno). The mean monthly temperatures in the growing seasons at these altitudes, were below optimum (11-14°C) for the development of the pathogen (Table 1) Hence, the incidence and severity were less. At lower altitudes like Ambo, Adet and Sinana, the mean monthly temperatures from June to October ranged between 15 - 18°C. The prevalence and severity were higher at these locations because many of the test entries were susceptible. The highest ACI score (19.5 - 60.0 score) on the check and susceptible varieties/lines confirmed the epidemic of the disease on the nursery in the first 3 years. Hence, Ambo, Adet and Sinana were identified to be the hot spot areas for leaf rust. The lowest leaf rust infection was registered in 1994 crop season. This is true not only for leaf rust, but for other rust diseases of barley and wheat (Table 2).

During 1989 crop season, only 6 and 2% of the entries were infected with moderately resistant and susceptible types of reactions at Ambo, respectively. The nursery was free from the disease in the other locations and years. Literature supports that barley not to be attacked severely by stem rust unless, under warm favorable condition on susceptible varieties (10).

In 1989, the food barley variety Ardu 12 60B and PGRC/E accession number 202632 were infected by the disease with severity of 5% and moderately susceptible reaction at Sheno. The former variety was also slightly affected at Ambo in 1992. Accordingly, barley stripe rust tends to be confined to the cooler and higher elevations (6, 10).

The inclusion of widely cultivated food and malting barley varieties in the nursery helped to monitor their performance to leaf rust. Some were susceptible when leaf rust inoculum pressure was high in the first 2 or 3 years, but in 1994 infection on most of them was low probably due to unfavorable weather condition and scarce inoculum density of the pathogen. According to the ACI score, 6, 2, 0 and 9 of them were classified as resistant varieties at 5, 3, 2 and 4 locations during 1989, 1992-1994, respectively. The malting barley varieties Proctor and Holkr and food barley varieties Ardu 12-60B and HB 100 were the most resistant entries across locations for 2 - 3 years. However, IAR/H/485 (standard check) Composite 29, Sheno Bulk and Beka showed low level of disease rating because the weather condition was unfavorable. The disease could be a potential danger for these varieties in locations in same environment with Ambo, Adet and Sinana.

The majority of the 125 PGRC/E accessions were susceptible in most of the years. Out of which, 6, 8, 0 and 9 of them were resistant across the test sites in the 1st, 2nd, 3rd and 4th year, respectively. Accession numbers 202551 -202553, 202603 and 202654 had ACI < 5 score across locations and in 3 out of 4 years. These accessions can be included in hybridization and selection to improve barley production because they perform better in disease resistance. The response of the differential varieties to leaf rust were variable. This might be due to the heterogenisity and/or differences in weather conditions for the leaf rust populations within and across locations and years. In all cases, two of the differentials namely Oderbrucker and Quinn were resistant. These varieties can be used as sources of resistance to the pathogen and their resistance in the course of years across locations might indicate the absence of newly appearing races. Knowing the existing races and monitoring new ones will help to breed rust resistant varieties).

Table 1. Mean weather data for barley **growing seasons at different locations**[*]

Location	Altitude (m)	Rainfall (mm)					Total	Temperature (°C)					Relative Humidity (%)				
		Jun	Jul	Aug	Sep	Oct		Jun	Jul	Aug	Sep	Oct	Jun	Jul	Aug	Sep	Oct
Ambo1	2225	156	192	191	114	34	687	17	16	16	17	17	76	84	85	77	62
Adet2	2240	117	372	218	145	97	949	18	17	17	17	18	60	76	76	72	60
Sinana**3	2400	47	109	125	-	-	281	15	15	(8.3)	(9.8)	(7.4)	-	-	-	-	-
Holetta4	2460	99	216	265	126	13	719	15	14	14	14	13	67	79	81	77	58
Sheno5	2700	100	287	306	101	0	796	13	13	13	12	11	63	79	70	80	-

[*] Mean of 4,3,1,3 and 2 year for Ambo, Adet, Sinana, Holetta and Sheno, respectively.

[**] ( ) = Minimum temperatures

Table 2. Resistance of the widely cultivated barley varieties to leaf rust for five locations.

Variety	ACI* value			
	1989	1992	1993	1994
Composite 24	7.0	10.7	30.5	1.3
Ardu 12-60B	1.0	6.7	14.0	0.5
HB 100	1.8	8.0	26.0	0.7
Sheno Bulk	23.0	27.4	60.0	1.8
IAR/H/485	9.6	16.7	46.0	1.5
Beke	3.2	16.1	34.0	0.4
Proctor	0.7	5.0	25.0	0.6
Holkr	0.4	0.9	28.0	0.6
Balkr	1.4	13.7	31.0	0.6

* Average Coefficient of Infection.

Table 3. Resistance of barley land races to leaf rust in five locations.

Accession No.	ACI value			
	1989	1992	1993	1994
202533	16.0	2.7	34.0	2.5
202534	15.8	3.4	21.0	7.8
202551	2.3	2.1	26.0	1.3
202552	5.0	2.1	15.0	1.3
202553	4.0	4.1	44.0	2.3
202573	3.2	12.0	36.0	0.5
202593	5.2	4.7	20.0	1.6
202603	2.1	4.0	24.0	0.5
202636	15.8	26.7	40.0	0.5
022654	3.5	1.4	10.0	0.5
IAR/H/485 (check)	9.6	16.7	46.0	0.7

Yield differences between land races and local check was observed, although the disease attacked both equally. Such kind of characteristics have been observed on Ambo local variety and landraces, where they appeared to be damaged equally by the same pathogen; yet the local one seemed to have suffered a greater yield loss. Thirteen land races were highly susceptible (60-100S and ACI > 25 score) to leaf rust and slightly infected with blotches, gave higher yields over the local check. The yields ranged from 2.0 - 2.8 T/ha., while that of the local check was 1.5 T/ha.. So, it is assumed that the 13 land aces possess some kind of tolerance to leaf rust are promoted to a tolerance study as such kind of cultivars will serve in the absence of the resistant ones (table 5).

In this study, leaf rust was the most widely distributed among the rust species that infect barley. In the first three years, the test materials were more susceptible to leaf rust at Ambo, Adet and Sinana than other locations. This indicates that these places could be used as screening sites as they were hot spot areas for the pathogen. Slight stem rust infection was observed on some entries at Ambo and stripe rust was recorded only on one food barley and PGRC/E accession at Sheno and Ambo.

There was no shift in resistance of the widely cultivated barley varieties to leaf rust. Proctor, Holkr, Ardu 12 60B and HB 100 remained resistant and Sheno Bulk as susceptible. Furthermore, accessions 202551 - 202553, 202603 and 202654 had lower ACI score (<5) across many locations and years. Besides this, Oderbrucker and Quinn were the most resistant varieties among the barley leaf rust differentials). The varieties that were found to be resistant to leaf rust can be accessions recommended to be used as sources of resistance to the pathogen.

Table 4. Resistance of barley leaf rust differential varieties in five locations

Variety	ACI value			
	1989	1992	1993	1994
Special	1.3	15.4	42.0	2.5
Reka I	0.8	8.7	37.0	1.6
Sudan	7.4	52.6	20.0	1.5
Bolivia	6.0	15.3	31.0	0.7
Oderbrucker	0.1	0.7	0.0	0.4
Quinn	2.0	0.7	0.0	0.2
Egypt	1.6	21.0	36.0	0.2
Gold	0.3	21.3	14.0	0.4
Lachtaler	0.4	28.1	34.0	0.3
IAR/H/485	9.6	16.7	46.0	0.7

Table 5. Tolerant PGRC/E barley accession to leaf rust at Ambo.

Accession No.	Days to heading	Days to maturity	Diseases		Yield/ha (Kg)	1000 Kwt (g)
			Leaf rust	Spot blotch (0-9 scale)		
202524	73	103	70S	1	2260.0	30.4
202537	62	103	80S	2	2811.0	37.4
202569	77	115	100S	tR	2036.0	34.0
202594	79	109	60S	1	2153.0	35.8
202597	56	91	80S	1	2518.0	44.0
202610	56	91	80S	1	2315.0	40.4
202618	56	91	80S	1	2723.0	45.0
202625	75	103	60S	1	2517.0	29.6
202632	73	92	80S	1	2051.0	34.8
202642	60	95	80S	1	2180.0	43.2
202643	60	95	100S	1	2325.0	46.6
202644	60	93	80S	1	2202.0	39.2
202648	58	93	100S	1	2612.0	43.4
B. Local	82	111	80S	2	1471.0	36.2

The variability in response of the differentials to leaf rust might lead to assumptions that the pathogen is heterogeneous and/or the variability was due to differences in weather conditions. Race analysis should be carried out to help in breeding for rust resistant varieties. The thirteen leaf rust susceptible land races, with high yields were recommended for tolerance study.

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Reaction of Some Potato Clones and Cultivars to Viruses at Holetta

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Abstract

The level of virus infection in some potato clones was determined during the 1992/93 off-season and 1993 main season at Holetta Research Centre and farmer fields. Field symptoms and Enzyme linked immunosorbent assay (ELISA) methods were used to detect potato leaf roll virus (PLRV), potato virus Y (PVY), potato virus X (PVX), and potato virus S (PVS). Most of the clones that looked diseased were found to be infected with PLRV and PVY. The ELISA test revealed that in the 1992/93 off season the combined incidence of PVY, PVX and PVS reached 51 percent of the total plant checked. On the other hand, PLRV was detected in about 11% of the samples. Based on field symptoms, of the 2838 plants assessed for PLRV, 557 (29.5%) seems to be infected by the disease.

In the 1993 main season, PVY was the most prevalent with a frequency of 46% followed by PLRV 39.3%. PVX, and PVS were less frequent (15% and 5%, respectively). Potato clones, CIP-382147.18, Sissay and CIP-384295.56 were found to be highly susceptible to PLRV, but variety AL-624, CIP-387014.16, CIP-388367.4, and CIP-383120.14 were found free of this virus. High accumulation of PVY and PVS were recorded on clones CIP-37801.3, AL-624, CIP-384321.3, CIP-374080.5 and CIP-387315.2 respectively. Virus infection seem to be more severe at the research centre than at farmer fields.

Introduction

Insect transmitted viruses diseases such as potato leaf roll virus (PLRV) and potato virus Y (PVY) are serious problems for potato production in places with the year round mild weather conditions. At present, close to 30 different viruses, excluding strains, have been affecting potato world wide (3). Among this viruses potato virus Y (PVY) potato leafroll virus (PLRV) potato virus X (PVX), potato virus A (PVA), potato virus M(PVM), and potato virus S (PVS) had been reported in Ethiopia (1,2,10). This diseases are increasing at an alarming rate in potato fields at Holetta Research Centre and in the surrounding farmers fields.

Significant losses in yield due to viruses have been reported by a number of workers (3, 6, 8, 9). Potato is being a vegetatively propagated crop, the virus accumulate in successive generations causing degeneration and subsequent yield reduction (6). The chance of introducing viruses into seed plots with symptomless plants is usually high. However, rapid and sensitive diagnostic tests are now available to screen large number of plant samples for their cleanness from viruses. The enzyme linked immunosorbent assay (ELISA), facilitate the indexing of selected clones for their purity from viruses prior to introducing them to seed increase programs. The purpose of this study was to determine the level of viral infection on various potato clones and cultivars with the aim of reducing their introduction to seed increase program.

Materials and Methods

The assessment was made on 17 potato clones during the 1992/1993 off-season and on 41 clones in 1993 main season at Holetta Research Centre and farmer fields around Holetta. The clones were at different experimental stage and mainly on seed increase. Though symptoms in potato vary widely with the virus strains and potato cultivars, incidence of viruses was determined visually about two months after planting. Assuming that plants from infected tubers would be randomly distributed in a field, fifty plants on each of five to ten alternate rows were observed for leafroll, mosaic, noticeable stunting and necrosis symptoms. To supplement the field diagnosis, ELISA tests for PLRV (4) PVY (5), PVX and PVS has been utilized using specific anti bodies obtained from the International Potato Centre (CIP). Leaf sample were collected from the lower, middle and top part of plants of each clones and cultivars in the field and brought to the laboratory and were subjected to the ELISA test.

Table 1. Results of ELISA test for Potato PLRV, PVY, PVX and PVS detection, 1992/93

Clones	Location	Samples			
		PLRV		PVY, PVX and PVS	
		+	-	+	-
Krolisa seedling	HRC	1	4	3	2
K-59-A(26)	"	0	5	4	1
UK-80.3	"	0	7	6	1
AL-575	" (screen house)	0	5	1	4
AL-624	" (screen house)	0	5	0	5
CIP-374080.5	"	3	2	2	3
CIP-378501.3	Farmer fields	1	9	6	4
Total		5	42	24	23
Percent incidence		10.6		51.1	

Virus detected (+) or not detected (-)

Results and Discussion

Visual field diagnosis showed that virus diseases of potato were complex, with similar symptoms and often confusing to the extent that any distinction made between the various virus disease was uncertain. During the 1992/1993 off-season the ELISA test showed that on the 17 potato clones tested, the combined incidence of infection by PVY, PVX, and PVS reached more than 50% while that of PLRV reached 11% (Table 1).

In the 1992 off-season field diagnosis the average incidence of PLRV was estimated at 26.9%. However, incidence in individual clones ranged from 0 to 87.5% (Table 2). The other type of virus diseases, very close to moptop which cause stunting, reduction of leaf size, mosaic and symptoms were also often observed.

Seemingly virus free plants from advanced clones at different experimental stages have been selected and undergone a serological test. The result of the test indicated that, 46.5, 39.5, 15.1 and 4.6 percent of the tested clones were infected with PVY, PLRV, PVX and PVS respectively (Table 3). No virus was detected on samples from symptomless plants. The released variety, CIP 378501.3, which was grown for seed increase at the centre and farmer fields around Holetta was found to be infected by both PLRV and PVY with higher intensity at the research fields than at the farmers fields. The candidate variety for release, UK-80.3 seem to be less contaminated with PLRV, PVX, an PVS but, low level of PVY incidence was recorded. Clones under multiplication in screen houses were found to be free of the above mentioned viruses (Table 3).

Table 2. Results of field diagnosis (visual) for PLRV at Holetta, 1992 off-season.

Clone	Total plants diagnosed	Plant with symptom	PLRV % incidence
AL 624	130	0	0
Sissay	124	97	78.9
CIP 378501.3	1440	226	15.7
" 384298.56	80	62	77.5
" 387014.16	80	0	0
" 382147.18	128	112	87.5
" 387346.13	154	13	8.4
" 387028.1	192	41	21.5
" 387346.2	174	6	7.4
" 388367.4	176	0	0
" 383120.14	160	0	0
Total	2838	557	26.9

Generally, the high virus incidence in the potato clones could be attributed not only to the field infection, but also to the significant aphid population in the storage, which may accelerates the level of contamination by PLRV and PVY. It is indispensable that, released clones should be cleaned from viruses prior to disseminating them to farmers. Finally selection of virus symptomless plants may offer relatively virus-free tubers, thus, both negative and positive selection methods are very useful in the production of seed tubers.

Table 3. Results of ELISA test for PLRV, PVX, PVY and PVS detection at Holetta, Research Center 1993 main-season.

Clone	Samples							
	PLRV		PVY		PVX		PVS	
	+	-	+	-	+	-	+	-
CIP 378501.3*	4	12	2	14	0	16	0	16
CIP 378501.3	10	2	12	0	5	7	0	12
UK-80.3	0	.4	2	2	0	4	0	4
Krolisa	2	2	0	4	0	4	0	4
K-59-A(26)	4	4	5	3	0	8	0	8
BR-113-112	0	4	4	0	2	2	0	4
CIP 382121.	4	0	2	2	2	2	0	4
CIP 384321.3	0	4	4	0	4	4	0	4
CIP 384376.3	2	6	6	2	4	4	0	8
CIP 374080.5**	0	6	0	6	0	6	0	6
CIP 374080.5	2	2	4	0	0	4	0	4
CIP 384298.56	4	0	0	4	0	4	0	4
CIP 384321.16	0	4	0	4	0	4	0	4
CIP 387315.2	2	2	0	4	0	4	4	0
Total	86							
Percent incidence	39.5		46.5		15.12		4.6	

[1] Viruses detected (+) or not detected (-)
* From farmer fields
**From screen House

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Performance of Maize/Bean Inter-cropping Systems Under Low and Medium Rainfall Situations: Disease Incidence

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Abstract

Maize/Bean Cropping systems experiments were conducted at Melkassa and Awassa during 1992 cropping season. Two early bean varieties with different growth habits were planted simultaneously with maize and relay planted one month after maize planting in different planting patterns in a randomized complete block design. The objective of the experiments were to evaluate the relationship that exists between maize and beans subjected to different planting patterns and planting schedules of bean varieties in reducing disease incidence and give sustainable yields under low and medium rainfall situations.

At physiological maturity rust infection was observed to be about 2% in intercrops whereas about 8% infection was observed in sole Awash-1. Similarly, about 4-8% infection was observed from physiological maturity. Maize/bean intercropping significantly reduced the incidence of bean rust at Awassa by inhibiting the spread of spores and due to wider spacing between bean plants in 2 rows maize/1 row bean intercrop and maize/bean mixed in the same row patterns. Contrary to this, incidence of anthracnose was higher in intercrops compared to sole beans. At maturity, treatments mixed cropped with Awash-1 and M-142 were infected by about 8-25% and 20-25%, respectively and their respective sole cultures were infected by about 3 and 5% for Awash-1 and M-142, respectively. But when beans were planted in 2 rows maize/1 row bean pattern the incidence was low ranging between 5-10%. The increase in incidence of this disease in mixed cropping might have aggravated due to shading from maize plants that created favorable microclimate for spore multiplication and dissemination mostly in broadcast patterns.

Both bean varieties planted simultaneously with maize in 2 rows maize/1 row bean intercrop pattern gave significantly higher yield advantage at both locations. Although these advantages were attributed to improved spatial arrangement and temporal difference resulting in better utilization of growth resources which in turn may also have reduced disease incidence in intercropped treatments. Thus, it was concluded that either of the bean varieties planted simultaneously with maize in 2 rows maize/1 row bean intercrop pattern could give sustainable yields in addition to reducing disease incidence and also may avoid risk of crop failure in the dryland areas of Ethiopia.

Introduction

Intercropping of different crop species buffer against disease losses by delaying the onset of the disease, reducing spore dissemination, or modifying micro-environmental conditions such as humidity, light, temperature and air movement. Moreover, spacing between rows and intra-rows, and spatial arrangements and planting schedule of component crops alter disease incidence in intercropping (Palaniappan, 1985). Epidemics are favored by morphologically and genetically uniform crops grown on large areas of land. In contrast, a combination of genetically different crops grown together in the same field does not provide the uniform substrate need by pathogen to multiply rapidly and acquire epidemic proportions. The incidence of disease therefore, may be reduced in intercropping, relative to sole cropping, but this is not invariably the case (Allen, 1990). Much depends on factors such as the host range of the pathogen species concerned, the relative sowing times and spatial arrangements of the associated crops. For example, anthracnose (*Colletotrichum lindemuthianum*) may be more severe on beans associated with maize, due to higher humidity and lower temperature in the canopy. Angular leaf spot (*Phaeoisariopsis griseola*) may also be worse on beans intercropped with maize, but when beans are intercropped with cassava, angular leaf spot may be slightly reduced due to differences in the microclimate (Moreno and Mora, 1984). On the other hand, the presence of a non host crop may reduce the disease incidence on the host crop. For example, cereal rust has been controlled by blending several genotypes, each possessing resistance to different races of pathogen, but with similar agronomic traits (Palaniappan, 1985). The spore dispersal of beans rust is reduced by intercropping (Moreno and Mora, 1984; Niguse, 1994; Amare, 1992). Bacterial diseases of beans (Xanthomonas campestris pv. phaseoli, and Pseudomonal syringae pv. phaseolicola) are also less severe in beans associated with maize than in sole cropping (VanRheenan et al., 1981; Muasku and Edje, 1982).

Planting density affects the disease incidence. With wind or soil borne disease spores, the wider the separation between individual host plants, the less likely it becomes that organisms infect new plants. However, the spread of wind borne diseases depends more on the number of dispersals than on the distance between the hosts. Virus diseases spread more easily to adjacent rather than to distant plants. The incidence of viral diseases is commonly less in intercrops of beans with maize because of lower populations or mobility of the vectors (Allen, 1983; Jamez and Moreno, 1983). Thus, in intercropping where plants of the same species are separated by plants of the other species a slower rate of dissemination would be expected.

Common bean suffers from a wide range of leaf, stem and root disease,s including common bacterial blight, rust, anthracnose, angular leaf spot, web blight and bean common mosaic virus. In Ethiopia, common bacterial blight (CBB), rust, and anthracnose are the most important and widely distributed, while the rest though important, are much more restricted in their distribution (Habtu, 1990). However, there is no information on the relative benefits of intercropping in controlling crop diseases in Ethiopia. The experiments were, therefore, conducted to identify crops and combinations that can increase yields on-sustainable basis and to investigate the effect of maize/bean intercropping on the incidence of diseases under low and medium rainfall situation.

Materials and Methods

The experiment was laid out in a Randomized Complete Block design (RCBD) with three replications at Melkassa and Awassa conditions. An early maize variety, Katumani composite and two bean varieties with different growth habits, Awash-1 (erect type) and M-142 (semi-prostrate) were planted simultaneously with maize and relay planted one month after maize planting. The planting patterns used were sole maize, sole beans, 2 rows of maize/1 row of beans, maize/bean mixed in the same row, maize in rows/bean broadcast and maize/bean both broadcast. The plant population maintained was 100% of sole maize and 50% of sole beans in all intercropped patterns, but 100% of sole crop were used in sole cultures of maize and beans.

Infestation of anthracnose, rust and common bean blight on beans was assessed in all experimental plots. Symptoms of rust and anthracnose reactions was observed at Anthesis at Awassa and disease assessment was carried out at growth phases of R6[flowering: the first flower opens], R7 [pod formation: the first pod appears being more than 2.5 cm long], and R8 [pod filling: the first pod begins to fill-seed growth], but no significant symptoms were observed for common bean blight at Awassa. Relatively no incidence of disease was observed at Melkassa. The rate of severity was assessed based on the following standard system for the evaluation of bean germplasm (CIAT 1991).

1-9 scale	1	2	3	4	5	6	7	8	9
% severity	0		2		5		10		25
Category	Tolerant			Intermediate					

Results and Discussions

Bean Rust

The rust incidence (8-20%) was significantly ($P < 0.05$) higher in beans under monoculture than when beans were planted under different planting patterns. Higher incidence was observed in maize row/bean broadcast and 2 rows maize/1 row bean patterns compared to broadcast patterns. There was no significant difference between sowing dates and planting patterns at R6 and R7 stages. However, significant interaction effects were observed at stage R8, and slightly higher incidence was observed in patterns relay planted beans. There was an increase in incidence at later growth stages highest incidence being at maturity in both varieties. There was no significant difference within intercrops while there was significant difference between sole beans and intercrops.

The severity of rust was higher in patterns planted with M-142 compared to patterns planted with Awash-1 (Table 2). Significant effects were observed only at R8 stage. The incidence in sole crops was as much as four times of intercropped treatments at R6 and

R7 growth stages, but even higher upto five times at R8 stage in some of the treatments. Moreover, M-142 planted in maize row/bean broadcast and 2 rows maize/1 row bean patterns were infected higher than broadcast patterns. Like the effects in sole crops, there was significantly higher incidence in patterns planted with M-142.

At stage R7 Awash-1 either planted simultaneously with maize or relay planted were infected by about 1%, whereas about 4% infection was observed in sole Awash-1 (Table 3). At stage R8, intecropped beans were infected by about 2% whereas about 8% infection was observed in sole Awash-1. Similarly, sole culture of M-142 was infected by about 4, 8 and 20% at R6, R7 and R8 stages, respectively. However, M-142 planted either simultaneously with maize or relay planted was infected by 1, 2 and 4% at R6, R7 and R8, respectively. The results revealed that M-142 was more susceptible to bean rust than Awash-1 at all growth stages in all planting patterns. Contrary to this finding, Davis et al., (1987) reported that there was more rust in simultaneous intercropping than in relay intercropping.

Pure stands bean resulted in high rust incidence than intercropped beans. This probably due to physical barrier of intercropped maize varieties on pathogen spread through wind and rain splash. This result is in agreement with the survey report of Habtu (1990) that there were differences in incidence and severity of bean rust among regions and farming practices. Rust incidence was lower on intercropped beans than their respective sole beans. In addition to the wider spacing between bean rows, shade and other micro-climatic effects under intercropping could also have effect on reducing the infection and development efficiency of the pathogen, which are in line with what was reported by Allen (1990). Thus, maize/bean intercrops buffer against rust incidence by delaying the disease or reducing spore dissemination.

Bean Anthracnose

The incidence of anthracnose is cropping systems is quite different than rust disease. The incidence of anthracnose was significantly higher in beans intercropped with maize than sole beans (Table 4). Sole beans were less infected by anthracnose when compared with beans planted simultaneously with maize or relay planted in different patterns. In general beans relay planted in different patterns were infected higher than beans planted simultaneously with maize in respective patterns. Beans planted either simultaneously with maize or relay planted in maize/bean both mixed in the same row was infected severely compared to other planting patterns.

In most intercropped patterns higher incidence of anthracnose was observed in plots intercropped with M-142 than with Awash-1 (Table 5). Moreover, sole Awash-1 showed less incidence than sole M-142. Higher incidence of 25% was observed in both varieties planted in maize/bean mixed in the same row and maize/bean both broadcast patterns at R8 growth stage. But when Awash-1 and M-142 were planted in 2 rows maize/1 row bean the incidence was lower to 10 and 20% at R8 growth stage, respectively. In all planting patterns, bean planted in maize/bean mixed in the same row and maize/bean both broadcast intercrops were significantly higher in incidence by anthracnose while 2 maize/1 bean intercrop and maize in rows/bean broadcast patterns were consistently lower in incidence.

Both bean varieties were infected less than their respective intercropped treatments planted either simultaneously with maize or relay planted (Table 6). At R6 stage either beans simultaneously planted with maize and relay planted Awash-1 were infected by about 3%, while no infection was observed in sole Awash-1. Sole culture of M-142 was infected by about 1, 3 and 5% at R6, R7 and R8 stages, respectively. However, M-142 planted simultaneously with maize and relay planted was infected by 3, 8, and 20%, whereas relay planted was infected by 4, 10 and 5%, at R6, R7 and R8 growth stages, respectively.

The higher anthracnose incidence in intercropped beans could be a result of micro-climate modifications imposed by maize crop; increase in relative humidity and shade which may favor the incidence of the disease. However, 2 maize/1 bean intercrop and maize in rows/bean broadcast planting patterns consistently had lower incidence and these patterns minimized the negative impact of the disease as a result of micro-climate alteration. The present findings are in line with the findings of VanRheen et al. (1981) Muasku and Edje (1982) that the incidence of anthracnose was severe on beans associated with maize, due to higher humidity and lower temperatures in the canopy. Besides, Amare (1992) reported that highest anthracnose incidence was observed in intercrops than sole crops as a result of higher humidity and favorable climate created by component crops. Though it is known that anthracnose causes considerable damage on intercropped beans, farmers in southern and eastern zones of Ethiopia are practicing it commonly. Hence the impact of this disease in intercropped beans call for thorough investigation on yield losses and its magnitude in biomass and economic yields.

Intercropping systems make excellent biological systems for reduction of pests, diseases and to suppress weeds. Maize/bean intercropping significantly reduced the incidence of bean rust and common bacterial blight at Awassa by trapping the spread of spores and due to greater separation between bean plants in 2 maize/1 bean intercrops and maize/bean mixed in the same row patterns. Contrary to this, incidence of anthracnose was higher in intercrops compared to sole beans. The increase in incidence of this disease might have been aggravated due to shading from maize plants that created favorable microclimate for spore multiplication and dissemination mostly in broadcast patterns. However, planting beans in 2 maize/1 bean intercrop resulted in less incidence as in sole beans.

Table 1. Effect of planting pattern and planting schedule of beans on bean rust incidence (%) Awassa.

Planting patterns	Planting Schedule					
	Simultaneous			Relay Beans		
	R6	R7	R8	R6	R7	R8
Sole Awash-1	2	4	8	---	---	---
Sole M-142	4	8	20	---	---	---
2 Maize/1 Bean Intercrop	1	2	3	1	2	4
Maize/Bean mixed in same row	1	2	3	1	2	3
Maize in row/Bean broadcast	1	2	4	1	2	5
Maize/Bean both broadcast	1	2	3	1	2	3
Intercrop Mean	1	2	3.3	1	2	4.3
LSD (0.05)				NS	NS	0.23

Table 2. Effect of planting pattern and bean varieties on bean rust incidence (%) at Awassa

Planting patterns	Bean varieties					
	Awash -1			Mexican-142		
	R6	R7	R8	R6	R7	R8
Sole crop	2	4	8	4	8	20
2 Maize/1 Bean Intercrop	0	1	2	1	2	5
Maize/Bean mixed row	0	1	2	1	2	4
Maize row/Bean broadcast	0	1	2	1	2	8
Maize/Bean both broadcast	0	1	2	1	2	4
Intercrop Mean	0	1	2	1	2	5.3
LSD (0.05)				NS	NS	0.23

Table 3. Effect of bean varieties and planting schedules on bean rust incidence (%) Awassa.

Patterns	Planting Schedule					
	Simultaneous			Relay Beans		
	R6	R7	R8	R6	R7	R8
Sole Awash-1	2	4	8	---	---	---
Sole M-142	4	8	20	---	---	---
Intercrop with Awash-1	0	1	2	0	1	2
Intercrop with M-142	1	2	4	1	2	5
Intercrop Mean	0.5	1.5	3	0.5	1.5	3.5
LSD (0.05)						
Note:- CV(%) between treatments				9.5	5.7	4.5
LSD (0.05) between treatments				0.32	0.40	0.37
Statistically analyzed based on bean germplasm standard						
Scale (1-9)						

Table 4. Effect of planting pattern and planting schedule of beans on bean anthracnose incidence (%) Awassa.

Patterns	Planting Schedule					
	Simultaneous			Relay Beans		
	R6	R7	R8	R6	R7	R8
Sole Awash-1	0	2	3	---	---	---
Sole M-142	1	3	5	---	---	---
2 Maize/1 Bean Intercrop	2	5	10	3	5	10
Maize/Bean mixed in same row	4	8	25	5	10	25
Maize in row/Bean broadcast	2	8	10	3	8	20
Maize/Bean both broadcast	4	8	20	4	10	25
LSD (0.05)				NS	NS	NS

Table 5. Effect of planting pattern and bean varieties on bean anthracnose incidence (%) at Awassa.

Planting pattern	Bean varieties					
	Awash-1			Mexican-142		
	R6	R7	R8	R6	R7	R8
Sole crop	0	2	3	1	3	5
2 Maize/1 Bean Intercrop	2	5	8	3	5	20
Maize/Bean mixed in row	4	10	20	5	10	25
Maize row/Bean broadcast	2	5	10	3	10	20
Maize/Bean both broadcast	4	8	25	4	10	25
LSD (0.05)				NS	NS	0.23

Table 6. Effect of bean varieties and planting schedules on bean anthracnose incidence (%) Awassa.

Patterns	Planting Schedule					
	Simultaneous			Relay Beans		
	R6	R7	R8	R6	R7	R8
Sole Awash-1	0	2'	3	---	---	---
Sole M-142	1	3	5	---	---	---
Intercrop with Awash-1	3	7	10	3	8	20
Intercrop with M-142	3	8	20	4	10	25
LSD (0.05)				0.2 1	NS	0.40
Note:- CV (%) between treatments				6.9 6	4.8 9	6.38
LSD (0.05) between treatments				0.3 9	0.4 5	0.78
Statistically analyzed based on bean germplasm standard scale (1-9)						

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Evaluation of Faba Bean Cultivars for Resistance to Black Root Rot (*Fusarium Solani*)

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Abstract

The production of faba bean (Vicia faba L.) in Ethiopia is constrained by several biotic and abiotic stress factors. One of the biotic factors is root rot caused by Fusarium solani. According to surveys made in some parts of Shoa region, average root rot incidence in Jiru, Gebre Guracha, Fiche, Debre Tsigie, and Ghoa Tsione was found to be 75%, 14%, 65%, 33%, and 55%, respectively. The disease is favored more by vertisol (black clay soil) than red soil.

Three hundred faba bean accessions were screened for resistance to wilt/root rot. A total of 45 accessions were found to be resistant/tolerant to the disease. Some accessions like Bichena 86-1, Bichena 86-3, 79533024-2ZPN-1 and Eth. 86-120-2 showed resistance, with 3-7% mortality.

Introduction

Faba bean (*Vicia faba* L.) is the most important grain legume grown in Ethiopia. However, its yield is very low under farmers' conditions. This is mainly because farmers mostly use local cultivars that are either poor yielders or susceptible to different diseases and other biotic and abiotic stresses (Habtu & Dereje, 1985; and Salt, 1981). In Ethiopia different diseases have been detected on faba bean. Among these, soil borne fungi such as wilt and root rots cause about 20-50% yield losses annually, and under severe condition this figure reaches 60-70% on farmers fields (Stewart and Dagnatchew, 1967 and Habtu and Dereje, 1985). Among the root rot causing fungi *Rhizoctonia solani*, *Fusarium solani*, *Fusarium oxysporum*, and *Pthium* sp. have been reported); *Fusarium solani* being the most important soil borne fungus in may parts of the country (Stewart and Dagnatchew, 1967, Habtu and Dereje, 1985). The ecological factors that influence or favor this root rot disease are high soil moisture, low nutrient supply, too wet soil, medium altitude, occurrence of other diseases and pests (Salt, 1981. Utical and Sulaiman, 1976). Developing resistant cultivars to this disease is highly desirable for economic and environmental reasons (Burke and Silberayel, 1965, Salt, 1981, Bruchl, 1983).

The objectives of this research work were to determine the incidence of the disease in some production regions and to evaluate indigenous and exotic faba bean germplasm against black root rot under field and greenhouse conditions.

Materials and Methods

Survey and identification: Extensive survey was made on farmers' field, and IAR/ADD sites where root rot of faba bean occurs every year. The survey sites included Ambo, Holetta, Inewari, Debresina, Selale and Jiru regions. Field assessment was made at 20 km intervals. Sample fields were selected randomly (not less than five points across the two diagonals in a field). Plants collected from 1 m^2 were and separated into healthy and infected and counted. Finally the average incidence of infected samples was calculated and the pathogens were identified.

Isolation & Multiplication: Five isolates of Fusarium solani were obtained from naturally infected root of local susceptible cultivars collected from Ambo, Inewari, Holetta, Selale and Bichena areas. The root pieces were disinfected, dried on filter paper and then planted on potato dextrose agar (PDA). After three days of incubation at 20-25°C. Pure culture were obtained by transferring pieces of mycelium from the colonies to slant PDA (Dixon and Doodson, 1970). From these, monospore cultures were produced. For inoculum production high concentration of microconidia was grown on a czpek-dox liquid medium (Dixon & Doodson, 1970, Habtu and Dereje 1985).

Effect on plant age: To identify the most susceptible stage of the plant to the pathogen inoculations were made 7 days before planting, during planting, 7, 14 and 21 days after planting. The inoculation was made by mixing spore suspension (1 x 10^6) spore/ml) sterilized soil in a pot. The design was RCBD with 4 replication. Data collected were: percent mortality, plant stand, seed yield, seed wt., pods/plant and seeds/pod.

Influence of soil moisture: Pot experiment was conducted at different levels of soil moisture to test the influence of soil moisture on the development of black root rot. The treatments were: Dry (750 ml water every 48 hrs), Normal moisture (750 ml water every 24 hrs), Wet (750 ml water every 12 hrs) and Saturated (750 ml water every 6 hrs).

Data collected were: percent mortality and plant stand.

Host resistance: A mixture of highly susceptible faba bean varieties (Kassa and Coll 1/78) were planted on sick plot developed during the short rainy season, to increase inoculum density (Nene, et. al., 1981). In addition, pure culture of Fusarium solani was prepared and mixed with autoclaved faba bean seed. After two weeks of incubation the culture was distributed evenly on the sick plot during planting the test materials (Nene, et. al., 1981). Three hundred test materials were planted during the main season in two rows of 4 m long. 40 cm parts, with 4 replications in RCBD. A susceptible check was planted after every two test rows. Data collected during the study were: root rot incidence, plant stand, yield seed wt. and pods/plant.

Results and Discussion

Survey and identifications: The surveys made in the Shoa region indicated that the average root rot incidence in Jiru, Gebre Guracha, Fiche, Debre Tsige, and Goha Tsione was founded to be 75%, 14%, 65%, 33%, and 55%, respectively. This showed that root rots of faba bean are widely distributed in the northern Shoa, but variation exist in their relative importance from region to region (Table 1).

Isolation and multiplication: The fungi associated with root rots were *Fusarium solani*, *Rhizoctonia* spp. *Pythium* spp. and, to a lesser extent, *Sclerotium rolfsii*. However, the most widely occurring fungus was *Fusarium solani.*

Effect on Plant Age: Early stages of the plant growth, when the soil was inoculated during planting and 7 days before planting, showed relatively high susceptibility to black root rot. It was observed that as the plant age increases susceptibility decreases.

Table 1. Incidence of root rot of faba bean under farmers' field condition

Pathogen	No. of fields	Crop stage		Altitude		Soil type	
		PF*	Pd*	2000-3000	>3000	BS~	RS~
Fusarium solanum	19.0	10.5	66.5	67.5	10.5	75.0	10.5
Fusarium oxysporium	11.0	25.0	45.0	55.0	10.0	55.0	18.0
Rhizoctonia spp.	10.0	10.0	18.0	18.0	7.0	18.0	10.0
Pythium spp.	7.0	10.0	10.0	10.0	7.0	10.0	10.0

* PF - pre-flowering
* Pd - podding

Table 2. Influence (percentage of wilted plant) of soil moisture on the development of root rot disease of faba bean

Condition of soil	Dry (control)	Normal moisture	Wet	Saturated
Inoculated soil	15	30	72	85
Non-inoculated soil	6	6	10	15

Influence of Soil Moisture: Faba bean planted on saturated and wet soils suffers more from the disease (85% and 72% infection, respectively) as compared to the check (Table 2).

Host resistance: Ninty-six cultivars of faba bean showed resistant and tolerant reactions to black root rot tested under field and blotter paper techniques (Table 3).

Accessions like Bichena 86-1 and Bichena 86-3 showed additional resistance to wilt. Multilocational testings for Fusarium wilt and root rots were carried out and Faba bean lines such as Bichena 86-1, Bichena 86-3, Eth. 86-120-2 were found to be resistant at several locations.

At the moment over 45 root rot resistance lines are available and are being used in the crossing program.

Table 3. **Reaction of some faba bean accessions to black root rot in the field and under laboratory conditions.**

Accessions	Field test		Yield (kg/ha)	1000 seed wt. (gm)	Lab. test	
	Stand (%)	Mor. (%)			pods/plant	Mor. (%)
Eth 86-120-2	98.9	5		433	15	5
Bichena 86-1	98.9	4	3470	390	16	4
Bichena 86-3	98.8	5	3910	401	15	6
83 Latt 30-168-2DZR-2	97.4	7	4371	396	15	6
79S33024-2-2PN-1	97.3	7	5010	433	16	3
L82085-1-2-3-1	98.1	6	4970	358	16	7
NC880C8-5	89.3	10	3311	437	14	12
CS20DK-33-8-2-2	69.9	23	2143	379	11	25
S83356-1	98.2	5	5031	600	14	7
282088-11-14	76.3	21	2080	301	13	19
74TA59-7-3-1	77.6	14	5344	349	14	10
PGRC/E Acc No 20-8102	70.3	22	2013	481	12	20
PGRC/E Acc No 20-8094	79.0	18	3610	342	15	17
L82087	65.2	21	2130	600	14	19
PGRC/E Acc No 27354	79.3	18	3520	397	15	16
PGRC/E Acc No 02-7355	80.1	16	3400	389	15	15
PGRC/E Acc No 02-7361	89.7	10	3100	439	16	15
PGRC/E Acc No 20-3128	**88.7**	**12**	**3200**	**320**	**15**	**10**
Local check	**45.6**	**27.9**	**1773**	**150**	**8**	**48.3**

Mor = mortality

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BUSINESS SESSION

Minutes of the General Assembly

1. President's Report

(Dereje Ashagari, ADCPD, MOA)

Members of the Crop Protection Society of Ethiopia,
Ladies and Gentlemen,

My report will be brief and will cover the following major topics.

- Status of membership
- Major activities carried out during the last one year.

Status of Membership

There are 213 registered members, of this 167 are regular, 42 associate and 4 student members.

At this juncture. I would like to report and remind at the same time that some 33 members have not paid their annual membership fee for the last two years.

Major Activities

The executive committee has met over 12 times since it was elected on April 27, 1994 and carried out many of its expected duties.

The following are some of the major activities that were carried out during the past year.

- As submission of activity and financial reports were required for the renewal of the Society's registration license, reports for the previous two years were prepared and submitted to the concerned government authorities.
- With proper follow up the Society's registration license was renewed for one year.
- An arrangement was made with a printing press for the printing of 2000 letterheads with the Society's address and emblem.
- CPSE members were invited to submit conference papers in November, 1994. Over

40 technical papers were received in the areas of plant pathology, entomology, rodent control, and integrated pest management. We were faced with difficulties in accommodating all papers to be presented in a two-day conference. Having no other choices, we were forced to select only those papers that were discussed the last two days. We express our regret to those whose papers did not have a chance to be presented. We would like to assure them that the rejection was by no means related to the quality of the papers.

- Abstracts of papers presented in the second annual conference were collected, edited and publish in a form of "Proceedings of the Second Annual Conference of Crop Protection Society of Ethiopia".

- Members of Executive Committee have represented our Society in various conferences of sister societies and other meetings. These include the seventh annual conferences of the Crop Science Society of Ethiopia, the second annual conference of the Ethiopian Weed Science Society.

- Executive committee members have also participated in meetings and in the preparation of the draft proposal of the constitution of the Ethiopian Agricultural Sciences Congress (EASC).

- Concerted efforts have been made in organizing the third annual conference.

With this briefing, I would like to thank again the Institute of Agricultural Research not only for its generous financial support but also for allowing us to use its halls and facilities. I also extend my appreciation to Ciba-Geigy, Al-Mesh pvt. Ltd, MaKobu pvt Ltd., Chemtex Enterprise, Filbert co., Rhone Populnec, and the Ethiopian Science and Technology Commission for their financial and or material support.

Thank you for your attention.

2. Ratification of the Constitution of EASC

It should be remembered that during the last Crop Science Society Conference, it was decided that the Ethiopian Agricultural Sciences Congress (EASC) be established to over see the activities of the different agricultural societies in the country. A committee consisting of the presidents and secretaries of the various agricultural societies was formed to draft the constitution of the Congress. The draft constitution was prepared and presented at the annual conferences of each agricultural societies during their annual conferences for ratification. The Third Annual Conference of CPSE has discussed the draft constitution article by article and ratified unanimously the establishment of EASC unanimously.

3. Election of Officers

The president and vice-president of CPSE have appealed to the conference that they were unable to finish their term in the executive office due to some personal problems. Although it was not an election year, the conference has accepted their resignation and elected Dr. Habtu Assefa of Nazret Research Center, IAR, as President and Ato Mesfin Tessera of the PPRC, IAR, Ambo, Vice-president, following election procedures stated in the Constitution of CPSE.

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