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Ethiopian Weed Science Society

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Ethiopian Weed Science Society

ETHIOPIAN WEED SCIENCE SOCIETY

The Ethiopian Weed Science Society (EWSS) is a national scientific and educational Society, open to all who are interested in weeds and their control. The Association was established on 23 November 1982 and inaugurated as a Society on 24 November 1992 on dissolution of the Ethiopian Weed Science Committee.

EWSS has the following objectives: encouraging and promoting the development of knowledge concerning weed science; promoting unity in research, extension, education, legislation, regulation and other matters pertaining to weeds; facilitating and assisting professional contacts between individuals and organizations; publishing and documenting weed science research results and making information available to users.

AREM

Arem is an annually published bulletin of the Ethiopian Weed Science Society (EWSS).

Arem was launched in 1992 upon the inauguration of EWSS. The former Ethiopian Weed Science Committee has been regularly producing annual conference proceedings up until its dissolution the same year.

Objectives of Arem

- to provide a forum for the dissemination of information concerning weeds and weed management.
- to create awareness about weed problems and new developments in weed science.
- to facilitate professional linkage among scientists.

The source of articles for Arem are primarily the regularly held conferences of the society but also volunteer papers which can meet the standard set by the society. Articles on all areas of weed science and weed management are considered for publication however original papers carrying information and findings on applied research are encouraged preferentially. Articles carrying brief but important information on weed alert and preliminary surveys are accepted as short communications to improve public awareness.

About this issue.....
Most of the papers for this issue come from the society's Fifth Annual Conference proceedings. Thus, introductory remarks presented during the opening session of the conference are included.

Address all communications regarding subscriptions, reprints and membership to the:

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Opening Address

Dr. Seifu Ketema
Director General, EARO

Mr. Chairman
Invited Guests
Dear participants
Ladies and Gentlemen

It is an honour and a pleasure for me to have been invited to address this important body of professionals at the 5th Annual Conference of the Ethiopian Weed Science Society.

Ladies and Gentlemen

The world population today is close to 6 billion and is expected to reach 8.5 billion by the year 2025. According to the figures provided by the recent World Food summit (FAO, 1996) the number of undernourished people in developing countries by the year 2010 will be between 700-800 million. To make matters worse, the increase in population seems to run parallel with a decrease in crop land areas. It needs little emphasis that crop production must therefore increase through crop intensification to avert future disasters.

In developed countries, the use of improved technologies has allowed greater flexibility in crop production while maximizing the benefits of costly inputs. Improved technology is now producing enough and, at times excess food in the developed world. At present agriculture has advanced so much that one farmer could feed almost 40 persons. Although this remains much to be desired in our part of the world many argue against acceptance of the assumption that transference of high input advanced solutions will be panacea to problems of low input farming systems of lesser developed countries. In the crop protection context, the continuing losses due to pests inequitably distributed across countries and agro-ecosystems, the evolution of pest resistance, shifts in pest problems in response to management, the chemical contamination of water sources and soil erosion through excessive cultivation attest to the need to develop systems of pest management that are suitable for local conditions.

Conference participants
Ladies and Gentlemen

Agriculture is the backbone of the Ethiopian economy. It is the very foundation on which the whole socio-economic structure of the nation is based. About 85 percent of the population of the country lives in rural areas and depends on peasant farming for its livelihood. Unfortunately, the constraints in this important sector of the economy are many and varied. First and foremost, unabated population growth seems to stand in the way of development and is encouraging progressive fragmentation of arable land to units that are economically inviable. This process is usually accompanied by increased infringement on forest reserves and marginal lands. The environmental implications are best known to many of you, and you are probably aware that environmental concerns have attained a global political dimension.

Ladies and Gentlemen

Diverse pest problems plague crops often resulting in severe losses. Weeds are the most underestimated of the whole pest complex but they are the source of multi-dimensional problems. Weeding ties up disproportionate percentage of the productive population and weeds result in an average yield reduction of 30%. Children and women are the ones who suffer most from the never ending and back-breaking activity. In spite of the large percentage of people involved with food production, however, the per capita food production has continued to decline while human population growth rate has continued to increase. In developing countries improved weed management technologies have not reached the small scale farmer, who has been left with technologies that have altered little with time. Progress towards improved methods of weed control for the subsistence farmer with limited financial and technical resources has been regrettably slow. Hence, the challenge facing scientists and the scientific community at large interms of making the many developments made in research known and exploited where every they can be of help is enormous.

Ladies and Gentlemen

It is often unnecessary to eliminate all weeds, but important to control or manage them so far as is necessary to prevent them from causing economic harm. In this regard, the world is moving in favor of a combination of compatible techniques and methods in an IPM to address its pest problem.

Although scientists have achieved great success with individual methods such as host plant resistance, biological control, and cultural control there is a need to integrate these and other methods in a way that provides the most cost effective control of weeds in each agro-ecosystem.

The various control methods must be viewed as complimentary and not as competitive or alternative approaches. This concept means changing to a multidisciplinary approach involving the knowledge and skills of various experts. The challenge is to find the best mix of methods and processes for a given agricultural environment.

Experience has taught us that understanding and controlling weeds is a complex task, and that single discipline alone cannot successfully lead to the total solution of the problem for stable and high yields of crops. It seems that this issue needs to be addressed in a much more broader context and in a much more comprehensive way.

The IPM concept features prominently here once more when one considers those issues. It is understood that IPM is the intelligent selection and use of pest control measures that will ensure favorable economic, ecological and social consequences.

By exploiting the results of up-to-date knowledge and research and applying all the available technologies, IPM offers real advantages for successful production of crops, not only in overcoming problems but also in helping many resource poor farmers in our country.

Ladies and Gentlemen

In such an occasion one can not pass without mentioning the *striga* problem that is quickly attaining national disaster status spreading like a bush fire. Realizing the enormous potential risk some regions are taking appropriate measures to curb parasite build up. Commendable activities are being made to mobilize human resources in Tigray and Amhara regions to prevent seed setting and consequently exhaust the seed bank in the soil. This is a move in the right direction and something that has to be adhered to, build up on and extended to other badly infested regions. Because experience from elsewhere has shown that communal approach is the best strategy available to make headway in the fight against the noxious weed.

In spite of all the research, there are few simple solutions to this problem and it is of an increasing importance in many parts of the world. In much of sub-Saharan Africa in particular, parasitic weeds pose a major threat to the food security of rural communities. In this and many other areas the parasites are weeds of small holder farming systems. The challenge is therefore not so much on how to control a parasite as how the small farmer can control a parasite and find it worthwhile to do so. In this regard once again priority should be given to multi-disciplinary work involving crop physiologists, agronomists and economists working together to develop integrated systems of relevance to local conditions.

Such efforts have to involve and make use of traditional knowledge. Farmers are aware of their problems and often understand the behavior of their pests but lack the knowledge of several biological features; particularly the means of reproduction and dissemination. This is where researchers and development agents should come in to provide essential information that farmers can use to enrich their knowledge base.

Ladies and Gentlemen

The Federal Government of Ethiopia is aware of the seriousness of the production problems the country is facing and the need to study it objectively with a view to adequately satisfy the food needs of the people. This realization has led to the launching of an intensive nation-wide extension initiative to aggressively pursue the food self sufficiency drive. Many of you are very well aware of the remarkable success our country has registered in recent years in its quest for food self sufficiency. It is incumbent on us to make sure that improved IPM based weed management technologies are part of those gains.

Agricultural progress must continue in this country at a greater rate. Plans to ensure that this will be done are in hand and embodied in the current agricultural development strategy of the country. As I have already indicated, the improvement in crop production over the last few years in this country has been quite spectacular. But there is plenty more work to be done and there is a lot of room for additional research.

A collaborative and concerted effort of research and extension agencies along with proper policies of the government may go a long way in improving the income base and over all development of the farming community.

Mr. Chairman
Ladies and Gentlemen

I would like to indicate that I am particularly happy to see scientists from various institutions within the country and a very useful mix of experience represented by scientists from IARCs with a deep and detailed knowledge of the situations regarding weeds and weed management.

I believe you will have an opportunity to make very definite progress towards setting guidelines and research strategies, in identifying and making bold suggestions for alleviating the priority problems.

We also look forward to an increasing cooperative research programs among federal and regional centers and IARCs to be able to solve our problems in a more coordinated manner.

I believe that the major goal of this conference must also be to consider how to cooperate best to make effective use of each other's time, abilities and knowledge, to strengthen the network of science through the bonds of friendship and common interest.

Finally, I would like to extend my sincere thanks to the organizing committee members, who have contributed their time and energy to bring about the realization of this conference. I wish you all the success in your deliberations and hope your discussions will be enjoyable and fruitful.

With these few words, I have the privilege and pleasure of declaring the Fifth Annual Conference of the Ethiopian Weed Science Society open.

Thank you

Closing Remark

Dr. Bateno Kabeto
Head, Crop Production and Protection Dept., MOA

Mr. Chairman
Conference participants
Ladies and Gentlemen!

First of all I would like to thank the organizing committee for inviting me to attend and deliver a valedictory remark at the end of this important event.

Ladies and Gentlemen!

It is hardly news to any one that economically weeds are perhaps the most important component of the total pest complex which also includes insects, mites, vertebrates, nematodes and plant pathogens.

Weeds cause crop losses of about 30% in developing countries. Farmers spend about 40% of their time removing weeds from their crops. Women and children work day after day in fields at the never ending job of hoeing and hand pulling weeds, which denies children from having the privilege of going to school and prevents women from having time to keep their homes.

The parasitic weed, *Striga*, is rapidly growing into a problem of major concern. It has spread dramatically in the past few decades, now occurring in almost all low and mid-altitude cereal growing regions. As a result the lives of many millions of people is threatened by this single species alone, *Striga* is most damaging in the dry and less fertile areas affecting farmers who can least afford the inputs required to minimize losses caused by this weed. Many such debilitating cases of weeds can be mentioned. Recent evidences indicate that the situation in our country is only getting worse. *Parthenium hysterophorous* and *Orobanche crenata*, two highly noxious species, for which there is so far no easy solution in sight, have incidentally been introduced into the country and have already become a nightmare to the farming community.

There are some encouraging and commendable developments on the extension side lately. Aggressive sensitization and awareness creation programs have led to extensive campaigns against *Striga* in Tigray and Amhara regions. This kind of initiatives have to be uplauded and every effort should be made to extend such activities to other badly hit areas in the country.

The problem of weeds is huge and so diverse and therefore represents an enormous challenge to weed science professionals.

Mr. Chairman
Ladies and Gentlemen!

I would like to point out the fact that it is often unnecessary to eliminate all weeds, but important to control or manage them so far as is necessary to prevent them from causing economic harm. There are various approaches to this:

1. Carrying out an applied research within the relevant crop management research programs.
2. Application of the IPM concept in a well thought and systematic manner to make out weed management packages more practical, cost effective as well as ecologically sound.

Some times weed researchers are most involved in simple herbicide trials, devoting significant percentage of their labour to this aspect. Such trials could be important, but other data on bio-ecology of weeds; various other management options should also be an integral part of an on-going weed research studies. The aim must be to develop a new approach for weed management suitable and compatible with the unique situation of a developing economy like ours.

Ladies and Gentlemen

Efficient weed control is basic to efficient and profitable agriculture. What do we do to improve efficiency? I think attention can be drawn once again to some suggestions on this line. A system for monitoring the changes in the major features of our rural scene. More specifically, we need to understand the dynamics of weed species and yet better their response to management. We need vastly economic data on the management options. Practical management tools with clear understanding of their use. We need to ensure that any system or technology developed is soundly based and accepted as valid by all the agencies interested in our changing agriculture. Finally, we need much better communication with the public and particularly the farmer. The success of any agricultural program will depend on the immediate implementation of research results together with appropriate awareness campaigns.

Mr. Chairman
Ladies and Gentlemen

We have now reached the end of this very successful conference. In analyzing the meeting as a whole there were themes that impressed me. And, the first and foremost was the diverse nature of the crop-weed management systems that have been discussed. In the process of these discussions the problems and uncertainties demanding research were pinpointed suggesting the inevitable -

more research. Well! This is said time and again, but please let us stress that we need more relevant research. Research to alleviate the age old but still most pressing problem of weeds effectively. Modern and efficient weed control methods integrated into the cultures of our people would give the opportunity to improve their standards of living through more productive work.

Mr. Chairman
Ladies and Gentlemen!

Finally, allow me to join the chairman of the society in thanking all the sponsors for making this conference possible for us to attend, to learn much, to meet each other, and to exchange our opinions and experiences.

I want to thank the organizers and others who have helped to make the conference a success. We all look forward to our next conference soon, to improved communication, friendship and collaboration.

With these remarks I now declare the Fifth Annual Conference of the Ethiopian Weed Science Society officially closed.

Thank you

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Orobanche problem in south Wollo

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Abstract

Broomrape, *Orobanche species,* is an obligate parasitic flowering plant. Complete faba bean yield loss by this weed forced farmers to replace fababean by wheat and oil crops. The distribution of the weed is increasing annually. To obtain relevant information on the introduction and distribution of the weed, survey was conducted on randomly selected 20 farmers' fields in two peasant associations. In this survey, information was also gathered regarding farmers attitude and local control practices. In view of the problem inflicted by *Orobanche* species, mutual effort among research centers, development organizations, individuals and others has to be strengthened to embark up on a coordinated program that could minimize the existing problem and retard further spread and dissemination of the weed to other areas.

Introduction

Some recently collected samples of *Orobanche* were identified by AAU herbarium as *Orobanche minor* and *Orobanche ramosa* contrary to earlier reports of the occurrence of *Orobanche crenata*. Crenate broomrape, *Orobanche crenata*, is an obligate parasitic flowering plant. Its main center of distribution is the Mediterranean region where large areas on which 5-100% infestation have been recorded. It is parasitic on a wide range of species of *Vicia faba* L.(faba bean), *Pisum sativum* L.(pea),*Lens culinaris* (lentil),*Cicer arietinum* L. (chick pea),*Vicia* species (vetch) and *Daucus carota* L. (carrot). Among the legume crops, *Orobanche crenata* infestation is severe on faba bean crop. Nevertheless, the damage inflicted by the weed varies from place to place.

Most species of *Orobanche* are annual and seeds are the means of reproduction for all species. One *Orobanche crenata* plant contains hundred or more capsules with numerous seeds. Seeds are produced in large quantities, 500 – 5000 per capsule being most common. Seeds of *Orobanche crenata* remain viable in the soil for more than 10 years (Linke et al.1989).

The species could also be found attached to some weedy host species in faba bean farms. Therefore, this ambiguity calls for systematic and area representative collections of the weed for further identification.

Due to the complete devastation of faba bean by *Orobanche*, farmers are forced to replace faba bean by wheat and oil crops in Kedijo peasant association (Dessie zuria woreda, south Wollo). The replacement of faba bean by other crops poses a problem as far as sustainable faba bean production is concerned.

Eventhough Wollo is home to one of the largest collections of faba bean accessions, increase in crop production has not been attained due to various production constraints. Of all the production constraints, the parasitic weed, *Orobanche*, is a priority problem that has become a hindrance to faba bean production. The infestation of the weed commences at flowering stage and continues through out the life span of the crop. It sometimes grows at the expense of a dieing faba bean crop.

This survey was initiated with the objective of determining the introduction, distribution, and intensity of infestation of the weed in south Wollo faba bean producing areas.

Materials and Methods

A field survey was conducted on a total of 20 randomly selected farms in two peasant associations (PAs), i.e. Kedijo and Haroye - Flagober. Kedijo is located in the south-west of Dessie, at an altitude of 2710 masl. Haroye – Flagober is found north of Dessie, at an altitude of 2690 masl. In each farm, a one quadrant (1m x 1m) sample was taken to determine the *Orobanche* species population and infested faba bean plants. Furthermore a structured questionnaire was used to assess the introduction and distribution of the weed and also to assess local control practices. Survey on the prevalence of the weed, *Orobanche*, was conducted at the time of flowering. At this stage the parasitic weed has fully matured and seeds are easily detachable from the main plant.

Scoring used to denote weed prevalence was:

0 - No *Orobanche*.

1 - Sporadic infestation.

2 - Infestation on the entire field.

3 - High infestation with up to two *Orobanche* shoots on most of the host plants.

4 - High infestation, more than two *Orobanche* shoots on all host plants.

5 - Faba bean crop barely visible because of severe infestation.

6 - Field completely destroyed by *Orobanche* (no yield expected)

Results and Discussion

Dessie zuria and Kutaber Woreda Department of Agriculture (south Wollo administration zone) have recently reported sever infestation of *Orobanche* in 19 potential faba bean producing peasant associations (Table 1) (Personal communication, 1999). The level of infestation varies between locality. Kedijo in Dessie Zuria and Haroye – Flagober and Luwcho, in Kutaber woreda, are seriously affected areas by *Orobanche*. Out of the 19 PAs, therefore, the two accessible peasant associations i.e. Kedijo and Haroye – Flagober were selected for the survey work.

Kedijo peasant association

The prevalence and distribution of the weed is extremely high at Kedijo than Flagober. Six weed species were dominant in legume crop fields. Among these, *Orobanche* is the most problematic weed that threatens the production of faba bean and other food legumes (Table 2). Owing to this problem, large faba bean farms have already been replaced by wheat and oil crops.

The undulating topography of the area (3-5% slope); along with dispersal agents of wind and flood, contribute to the spread and possible contamination of grazing areas by the parasitic weed.

All surveyed faba bean farms, size of which ranged from 0.02 – 0.50 ha., were infested with the weed. The prevalence score was four with infestation level at more than two shoots per faba bean plant. On a 1m x 1m area, 41 – 248 shoots were counted. From the same sample area, an average number of 123 *Orobanche* shoots and 12 live but parasitized faba bean plants were counted. The average number of *Orobanche* shoots on a single faba bean plant was seven (Tables 3). In Kedijo and other areas, the practice of harvesting whole green pods is becoming customary so as to prevent further yield loss by the weed. According to farmers, crop loss could reach as high as 75 – 100 %.

Table 1. Infested faba bean producing areas

Woreda	Location	PA
Dessie Zuria	South West of Dessie	Kedijo Kedijo – Kimir dingay Gerado Abaso kotu Asegedo Kurkur Tita Ayata
Kutaber	North of Dessie	Haroye – Flagober Luwcho Guasameda Sironadala Segon Manoshnabarkana Elsanadoshign Kundigergero Derae Tkananaminatash Duguguru

Table 2. Major weed species in Kedijo peasant association

No.	Vernacular name	Botanical name
1	Dimerech	*Orobanche* species
2	Dehakiber	N.I
3	Leglego/Kechkech	*Polygonum aviculare*
4	Akenchira	*Galinsoga parviflora*
5	Tult	*Rumex nepalensis*
6	Wagima	*Trifolium rupellianum*

N.I = Not Identified

Table 3. *Orobanche* shoot count and infestation level at Kedijo peasant association

Surveyed plot No.	Area (ha)	Weed prevalence score (0-6 scale)	Live* f.bean shoots/m^2	Dead** f.bean shoots/m^2	Weed count/ m^2	*Orobanche* shoot/plant (mean)
1	0.03	6	0	67	248	14
2	0.06	4	30	6	69	6
3	0.06	4	17	33	115	5
4	0.05	4	17	51	108	7
5	0.02	4	8	28	55	4
6	0.09	5	9	59	149	6
7	0.13	6	0	18	127	9
8	0.50	4	14	24	150	14
9	0.50	3	16	15	41	2
10	0.13	4	4	34	164	6
11						
	Total	3 – 6	115	335	1226	2 – 14
	Mean	4	11.5	33.5	122.6	7

*Infested faba bean shoots with harvestable green pods
**Dead faba bean shoots (no harvestable product)

Farmers indicated that the weed appeared for the first time in 1983 GC in Dehit area (Goshi – locality). But they were not familiar with the weed and could not realize the potential threat at the time. This area seems to have been the source of infestation for all other areas in Kedijo. How the weed was introduced into the country at large is still unknown.

There was an erronious speculation that the species occuring in the area was *Orobanche crenata* brought in with imported crop seeds (Assefa and Endale, 1994).

Farmers continually uproot the weed, 4 – 5 times, with a local implement called Ankase (an implement with sharp pointed end) and mattock. The removal of the weed by hand pulling is laborious as new flushes of the weed appear every 2 – 3 days after weeding. In the effort to eradicate the weed by hand pulling much labour is wasted which otherwise could be used for other farm activities.

There are conflicting ideas among farmers concerning the impact of soil fertility on the weed. Some farmers suggest that the application of manure reduces the damage and hence helps the crop to resist the attack. Others suggest that cattle manure aggravates the infestation as it can contain weed seeds.

Haroye – Flagober peasant association

The area is surrounded by chain of mountains and degraded hills. Very few tree plantations are found at the top of the mountains only. Hillsides and low-lying areas are all allocated for faba bean production. Fifteen weed species were dominant in legume crop fields. Among these, *Orobanche* is the most important weed that impedes the production of faba bean and other food legumes (Table 4).

Orobanche existed in the area since 1980, in the low elevation localities, growing among shrubs and bushes. Farmers of both high and low elevation areas were using the weed to treat wounds and sores. Farmers pointed out that the primary sources of infestation for Haroye – Flagober peasant association were neighbouring lowland areas, from where farmers have brought the weed to their area as a medicinal plant. Furthermore, the weed was thought to have been introduced from Kedijo area by means of farm tools and planting materials (seeds).

Table 4. Major weed species in Haroye – Flagober peasant association

No.	Vernacular name	Botanical name
1	Dimerech	*Orobanche* species
2	Asendabo	*Gastridium phleoides*
3	Akenchira	*Galinsoga parviflora*
4	Geten	*Haplocarpha schimperi*
5	Leglego/Kechkech	*Polygonum aviculare*
6	Muja	*Snowdenia Polystachia*
7	Wagima	*Trifolium rupellianum*
8	Enkirdad	*Lolium Tomulentum*
9	Webelo	*Avena sativa*
10	Mech	*Guizota scabra*
11	Tult	*Rumex nepalensis*
12	Wuran	*Digitaria abyssinica*
13	Gicha	*Cyperus rigidifolius*
14	Yewuha sar	N.I
15	Aluma	*Amaranthus hybridus*

During the assessment it was noticed that the weed was as tall as and sometimes even taller and more vigorous than the faba bean crop. Frequent hand weeding (on average five times) is the usual practice. High frequency of weeding needed to control *Orobanche* creates shortage of labour for the other farm activities. At Haroye – Flagober, one can observe severe infestation of *Orobanche* from flowering up to the harvesting period of faba bean. Seeds of the weed that shatter become the source of infestation for subsequent seasons.

All surveyed fababean fields, area of which range from 0.02 – 0.25 ha were infested. The average prevalence level was four with more than two shoots per faba bean plant. On a 1m x 1m area, 43 – 301 *Orobanche* shoots were counted. From the same sample area an average number of 125 *Orobanche* shoots and 15 live but parasitized faba bean plants were recorded. The average number of *Orobanche* shoots on a single faba bean plant was six (Tables 5). In Haroye – Flagober and other neighbouring areas, the practice of harvesting green pods is becoming customary so as to prevent further yield loss due to increased infestation in the ripening crop. According to farmers, crop loss could reach as high as 75 – 100 %.

Farmers perceive the application of manure as a means of dissemination as it can contain live weed seeds. On the contrary, fields fertilized with inorganic fertilizers (DAP and urea) contain relatively lower weed population and provide better yield.

Farmers continually pull out the weed 4 – 5 times. Such practice, however, encourages new flush of weed growth and thus increases labor requirement.

Table 5. *Orobanche* shoot count and infestation level at Haroye – Flagober peasant association

Surveyed plot No.	Assessed farm size (ha)	Weed prevalence level (0-6 scale)	Live* f.bean (shoots/m^2)	Dead** f.bean (shoots/m^2)	*Orobanche* species (count/ m^2)	Shoots/ f.bean plant (mean)
1	0.13	5	8	46	119	6
2	0.02	4	21	0	109	6
3	0.03	5	10	27	301	8
4	0.25	5	9	25	108	8
5	0.13	5	0	58	148	11
6	0.20	5	7	33	154	5
7	0.13	4	28	49	57	5
8	0.25	3	26	39	88	4
9	0.25	4	30	19	43	4
10	0.25	1	8	26	120	5
Total		1 – 5	147	322	1247	4 – 11
Mean		4	14.7	32.2	124.7	6

*Infested faba bean shoots with harvestable green pods

**Dead faba bean shoots (no harvestable product)

Conclusion

Orobanche infestation is increasing and spreading into new areas. Farmers are being forced to abandon faba bean production and replace it by other cereal and oil crops. This new development can eventually take faba bean out of production leading to dire consequences. Faba bean is a highly valued crop in the area as:

- a protein rich and less expensive food, especially fed to children at any time of the day,
- a meal served at the time of mourning and other social gatherings and
- a crop needed for soil fertility maintenance.

In the affected areas, the problem of *Orobanche* goes to the extent of preventing engagement of couples. Because of repeated crop loss, due to the parasitic weed, adults flee to urban areas in search of jobs.

Effective control measures are required for host specific parasitic weeds such as *Orobanche*. To stimulate further research on the control of the weed, more information on the biology of the parasite is needed (Linke et al. 1989).

Furthermore, research centers have to give more emphasis to the identification of the existing *Orobanche* species, developing resistant varieties, integrated weed, crop and soil management practices and the inclusion of physical, biological and chemical control measures to solve the parasitic weed problem in the already infested areas. Above all, mutual effort among research institutions, development organizations, and other stake holders has to be strengthened to launch a coordinated program that can practically arrest the dissemination of the parasitic weed to other areas.

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Major weed species in the Southern Nations, Nationalities and Peoples Region

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P.O.Box 6, Awassa

Introduction

In the Southern Nations, Nationalities and Peoples Region (SNNPR) smallholder farmers spend more than 40% of their time on weeding. Yet, inspite of all the effort, weeds still cause substantial losses in crop production, possibly as much as all other pests and diseases combined. Understanding the nature and dynamics of noxious weeds and the ability to forecast infestation levels is a prerequisite for effective control and thus increase in food production which, is a pressing need in the region. It is also vital to know their biology and ecology.

Some highly troublesome weed species have widely spread over the past few years colonizing huge farm areas, and affecting crop production and human health. This paper describes the most economically important species in SNNPR.

Striga siatica

The genus ***Striga***, belongs to the family ***Scorphulariaceae*** and contains about 60 species. *Striga asiatica* is the most widely spread and damaging species in Konso and Derashe special weredas. In Konso, the species is called '*Korba*'/'*Dhawa*', while in Derashe it is known as '*Qoesha*'. The Striga ecotype, found in the area, has small (10-30cm) and red flowers.

Intensive sorghum cultivation due to the ever increasing population and the almost non existent quarantine restrictions have led to the spread and build up of the weed in both weredas.

Yield loss due to the parasitic weed is usually very high and can reach 100%, depending on the level of infestation and the time of attack. Arable lands are often abandoned because of prohibitive *Striga* infestation.

Repeated hand weeding is the commonly practiced control method in these areas. Farmers also apply manure to their fields to help reduce infestation.

Sonchus arvensis

Sonchus is a perennial broad leaf weed. Plants are erect with soft stems, which exude milky latex upon cutting . Flowers are yellow in colour. It is an aggressive weed and produces upto three tonnes of dry matter per hectare in one growing season. The weed spreads by horizontal stems that give rise to new aerial shoots.

S. arvensis is a problematic weed in cotton, sorghum, maize, sweet potato and tef in Arbaminch, Derashe and Konso areas.

Seedlings are easily controlled by hand weeding. However, mechanical control becomes difficult, late in the season, on plants with well developed underground horizontal stems. Above ground shoots can be removed manually but resprouting from underground rhizomes is rapid, rendering the exercise ineffective.

Parthenium hysterophorus

P. hysterophorus also known as white top, white head, congress weed and carrot weed is an erect annual herb with alternate, deeply-dissected leaves and branched inflorescence bearing white flower heads. Plants can grow up to 2m tall.

The weed has originated in tropical America and was introduced into Africa, Asia and Oceania in cereal and grass seed shipments during the 1950s. In Ethiopia, it first appeared in Eastern Harrarge, later spreading to Wello, Arsi Eastern Shoa and SNNPR, around Awassa and Arbaminch. *Parthenium* is known for its allopathic effect on other plants. It releases phytotoxic substances such as: ferulic, caffeic, chlorogenic, P-coumaric, P-hydroxybenzoic acids, parthenin, ambrosin and coronopilin, which highly inhibit germination and growth of several plant species (Dayama, 1986, Swaminathan at. Al., 1990) and also causes allergic contact dermatitis and respiratory problems in humans and livestock (Aued and Meced, 1987).

Repeated ploughing, during land preparation, reduces weed population in infested fields. In a small area, hand hoeing, during the early growth stages, can help delay and prevent flowering. Hoeing of mature plants is ineffective as it induces re-growth from crown buds.

Argemone mexicana

Argemone is prickly annual herb with alternate leaves and yellow flowers. The leaves are bluish green, with sharp spiny margins. The fruit is spiny. Upon cutting, the plant exudes a yellow sap which causes allergy in humans. The weed grows throughout the year, even during dry season.

The species is highly troublesome around Awasa, Alaba, Boditi and Arbaminch on maize, sweet potato, tef, cotton and other crops. Lately, the weed is rapidly spreading into the different zones in the region along with building and planting materials and animal feed.

Early growth of *A.mexicaca* can easily be removed manually, however, spiny leaves and fruits make hand weeding of mature plants difficult.

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Biological control of weeds with particular reference to *parthenium hysterophorus* in Ethiopia

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Introduction

Insects and diseases are major constraints to crop production. Hence it is not surprising that they can also be major constraints of non-crop plants. When plants are introduced into countries or habitats where they are exotic their associated insects and diseases, many of which are host specific or restricted in their host range, are frequently left behind. Freed of these specialised natural enemies, exotic plants may be far more vigorous in their adventitious range than in their natural range and many become invasive, affecting agriculture, grazing, forestry and natural habitats.

Biological control is the use of natural enemies to control pests. This is usually applied in one of three ways:

- Introduction (or classical) - introducing exotic natural enemies from the area of origin of the weed.
- Augmentative – the production and release of key natural enemies, often at a time when these are normally scarce, e.g. early in season. For weeds this is only experimental so far, and is unlikely to be very cost effective in the near future, unless it can be implemented at the farm level (Cock 1994).
- Inundative – the mass production and release of selected natural enemy (indigenous or exotic) in a similar manner to a specific herbicide. This is only really practical for plant diseases which can be produced in the laboratory. The economics of such an approach are likely to be challenging, but it is well worth pursuing for major problem weeds which are otherwise targeted by control programmes.

This paper is concerned primarily with the application of classical biological control to weeds, and in particular to *P. hysterophorus*.

A major difference between biological control of weeds and biological control of insects is the need for detailed studies to assess the potential host range of biological control agents being considered for introduction. This is done by host specificity testing based on some of the following:

- field observations on closely related plants in area of origin (arthropods & pathogens),
- evaluation of life cycle/life history and biology (pathogens & insects), and behaviour (arthropods),
- inoculation tests (pathogens)
- oviposition tests (arthropods),
- starvation tests (arthropods),
- feeding choice tests (arthropods),
- field experiments in area of origin (arthropods and pathogens).

The degree of host specificity required will depend upon what plants closely related to the target are indigenous or of commercial value in the target country. The International Plant Protection Council has prepared a Guideline on the Introduction of Biological Control Agents which provides guidance for any country considering the implementation of biological control.

This paper summarises the progress to date on biological control of *Parthenium hysterophorus*, and then considers what might be done about this weed in the case of Ethiopia.

Parthenium hysterophorus

Parthenium hysterophorus is well known already in Ethiopia, following its discovery in the country in the 1980s. Its status and biology has been addressed at meetings of the Ethiopian Weed Science Society in previous years (e.g. Fasil Reda 1994, Frew Mekbib *et al.* 1996; see also Navie *et al.* 1996), so these areas will not be considered here except to note the following aspects relevant to biological control:

- Taxonomically it belongs in the sub-tribe Ambrosiinae, tribe Heliantheae of the Asteraceae or Compositae; the sub-tribe Ambrosiinae includes *Ambrosia* and *Xanthium*, two important weed genera, other sub-tribes of Heliantheae include *Helianthus* (sunflower), and various ornamentals including *Coreopsis, Cosmos, Dahlia, Gaillardia* and *Zinnia*.
- *Parthenium* occurs in at least two biotypes in its natural range which is the region surrounding the Gulf of Mexico as well as central South America; the form exotic in the Old World originates from North America with its evolutionary centre most probably being northern Mexico and southern USA.
- It is widespread in diverse habitats in the Neotropics and a problem weed in India and Australia (Queensland), suggesting its potential range in Africa is enormous.

- Reproduction is entirely by seeds.
- Growth proceeds through a rosette stage to the flowering plant.

Biological control of *parthenium hysterophorus*

Biological control agents already used

The search for biological control agents for *Parthenium hysterophorus* began in 1976 and intensive work was carried out from 1977 to 1981 in Brazil and Argentina and from 1978 to 1983 in Mexico by the Queensland Department of Lands (now Queensland Department of Natural Resources) and CIBC (subsequently IIBC and now CABI Bioscience) (McClay *et al.* 1995). Less intensive studies continued on insects until 1991 and on pathogens until very recently (Evans 1997a, b).

Over 144 phytophagous arthropods were found to feed on *Parthenium* in the Neotropics, and 13 of these were considered to be restricted to the sub-tribe Ambrosiinae (McClay *et al.* 1995). As a result of these studies eight insect biological control agents were studied in detail, initially in Mexico and subsequently under quarantine in Australia, before being released in Australia (McFadyen 1992; Evans 1997a, b).

In the 1980s the work was expanded to include pathogens. Surveys were undertaken in the Neotropics by staff of CABI Bioscience focussing on Mexico. At least ten pathogenic fungi were recorded to be associated with *P. hysterophorus* in its native range. Work concentrated on the evaluation of a rust fungus, *Puccinia abrupta* var. *partheniicola*, as a potential biocontrol agent, which was subsequently introduced into Australia in 1991. The evaluation of a second rust species, *Puccinia melampodii*, has just been completed and its introduction into Australia is imminent (Evans 1997a, b).

Details of the biological agents which have been introduced into Australia and India are summarised in Table 1, while information on other potential biological control agents being studied is summarised in Table 2.

Steps towards biological control of *Parthenium hysterophorus* in Ethiopia

Biological control is an obvious tool for inclusion in any integrated management plan for *Parthenium* in Ethiopia.

Table 1. Biological control agents used for *Parhtenium hysterophorus.*

Species and classification	Origin	Biology	Host specificity	Introductions	Selected references
Epiblema strenuana (Walker) (Lepidoptera, Tortricidae)	Mexico	ova laid on stems and leaf undersurface; small larvae are leaf miners, then bore into stems, and a gall of 10-15 mm is formed by the plant; pupation in gall; life cycle 30-40 days; fecundity 100-1300 ova/female; long dispersal range (up to 20 km); multi-voltine (2-3 generations/year in Mexico, 4-6 generations/year in Australia)	49 species tested; also feeds on *Ambrosia artemesiifolia* and *Xanthium occidentale* (weeds). Further tests in India suggest niger seed can be attacked; this needs field verification in Australia.	Australia: Years of release: 1982-83; Year of establishment:1983; Prevalence in Queensland: widespread; Impact: high, but population of *E. strenuana* declines in dry weather.	Dhileepan *et al.* 1996; McFadyen 1985, 1989, 1992.; Navie *et al.* 1998

Zygogramma bicolorata Pallister (Coleoptera, Chrysomelidae)	Mexico	ova laid singly or in small groups on leaves and flowers; nocturnal larvae feed on leaves; pupation in soil; adults feed on leaves, life cycle 8 weeks; multivoltine, 2-3 generations/year in Mexico, 4 or more in Australia; adults can live 2 years; slow dispersal	51 species tested for Australia; adults can feed on several Compositae, but larval development only on *Parthenium*, detailed tests on 11cultivars of sunflower, also feeds on *Ambrosia artemesiifolia*. Additional testing in India, including detailed study on sunflower following field observations of feeding.	Australia: Years of release 1980-82 Year of establishment 1990 Prevalence in Queensland: Restricted Impact: high in Central Queensland India: Released: 1984 (Bangalore), 1991 (Karnataka) Established 1984 Impact: high	Jayanth 1987; Jayanth & Nagarkatti 1987; Jayanth *et al.* 1993, Kumar 1993.
Listronotus setosipennis Hustache (Coleoptera, Curculionidae)	Brazil & Argentina	adults nocturnal, feeding on leaves and flowers, ova laid in flowers when available, otherwise leaves or stems; small larvae in flowers or flower stalks; larger larvae are very damaging in lower stem sections; pupation in soil, life cycle 27-42 days; adults live up to 8 months	Host range testing on 65 species, with detailed studies on 6 cultivars of sunflower	Australia: Years of release 1982-85 (55,000 adults) Year of establishment: 1983 Prevalence in Queensland: widespread Impact: moderate	Dhileepan *et al.* 1996; McFadyen 1985; Wild *et al.* 1992

Smicronyx lutulentus Dietz (Coleoptera, Curculionidae)	Mexico	seed feeding larvae; one seed per larva; 237 ova/female (cf. 4963 seeds per plant)		Australia: Years of release: 1981-82 Year of establishment: 1996 Prevalence in Queensland: restricted Impact: low	Dhileepan *et al.* 1996; McFadyen 1985, 1989; McFadyen & McClay 1981.
Stobaera concinna (Stal) (Homoptera, Delphacidae)	Mexico	Sap-feeder	Also feeds on *Ambrosia artemisiifoilia.*	Australia: Years of release: 1983-84 Year of establishment: 1992 Prevalence in Queensland: Occasional Impact: none	McClay 1983; McFadyen 1985, 1989
Buccalatrix parthenica Bradley (Lepidoptera, Buccalatricidae)	Mexico	Ova laid on leaves; leaf-mining larvae; pupation in cocoon usually on leaf under surface; life cycle about 25 days.	Tested on 63 species, and only developed on *Parthenium* spp.	Australia: Years of release: 1984 Year of establishment: 1987 Prevalence in Queensland: widespread Impact: no obvious impact although occasionally up to 50% of leaf area can be destroyed locally.	McClay *et al.* 1990; McFadyen 1985, 1992.
Platphalonidia mystica Rakowski & Becker (Lepidoptera, Tortricidae)	Argentina	stem-galling larva	Tested on 61 species and 11 cultivars of sunflower tested; slight feeding on *Ambrosia*, *Xanthium*, sunflower and Dahlia was not considered to pose a problem.	Australia: Years of release: 1992-96 Year of establishment: ? Prevalence in Queensland: not known Impact: not available	Dhileepan *et al.* 1996; Griffiths & McFadyen 1993; McFadyen 1992

Conotrachelus **sp.** (Coleoptera, Curculionidae)	Argentina	adults nocturnal and feed on stem tips and leaves; oviposition in feeding scars at leaf axil; larvae bore into stem and cause gall formation (10 mm); pupation in soil; life cycle 13-16 weeks; 3 generations/year in Argentina; adults live 3 months normally	Host specificity tested on 52 species, plus 6 cultivars of sunflower	Australia: Years of release: 1995-97 Year of establishment: ? Prevalence in Queensland: not known Impact: not available	Dhileepan *et al.* 1996

Puccinia abrupta var. *partheniicola* (Jackson) Parmelee (Basidiomycota, Uredinales)	Mexico	rust fungus of leaves, stems and flowers; infection hastened leaf senescence, decreased life span and weight of plants and reduced flowering; normally above 700m in Mexico; climate restricted (requires lower temperatures, < 20 °C, and dew for germination and infection)	103 species and 17 cultivars of sunflower tested.	<u>Australia</u>: Years of release: 1991. Year of establishment: 1994. Prevalence in Queensland: restricted to southern areas. Impact: initially promising results appear to be limited by adverse weather <u>Kenya</u> Present in Kenya, where *Parthenium* is not a significant problem. <u>Ethiopia</u> Reported to be present in Ethiopia but needs verification	Parker *et al.* 1994

Table 2. Biological control agents for *Parhtenium hysterophorus*, under study but not yet released anywhere.

Species and classification	Origin	Biology	Host specificity	Introductions	Selected references
Carmenta ithacae Beutenmuller (Lepidoptera, Sesiidae)	Mexico	oviposition anywhere on plant; all plant stages attacked; larva bores in tap root and crown; pupation in root or crown.	under study.	**No releases.**	
Thecesternus hirsutus Pierce (Coleoptera, Curculionidae)	Mexico	large flightless weevil; univoltine; adults feed on leaves; oviposition in soil at plant base; external feeding on the tap root cause a gall-like swelling; pupation in earthen cell at feeding site	under study, apparently narrowly polyphagous	**No releases.**	**McClay and Anderson 1985**
Puccinia melampodii (proposed as a forma speciales of *P. xanthii)* *P. melampodii* = *P.xanthii* f. sp. nov. (Basidiomycota, Uredinales)	Mexico	Causes individual necrotic leaf spots which coalesce over time to result in die-back of the whole affected leaf; secondary infections lead to severe debilitation and sometimes death of the plant; normally below 600m in Mexico.		**Release into Australia has just been authorised and is scheduled to commence in late summer / autumn1999.**	**Evans 1997b**

The steps for a biological control programme can be summarised as follows:

1. Survey of distribution and impact of *P. hysterophorus* (agricultural, social, economic, medical) in Ethiopia.

2. Survey of natural enemies present on *P. hysterophorus* in Ethiopia - likely to be few and ineffective.

3. DNA analysis of Ethiopian material of *Parthenium* in comparison with other populations, including Kenya, India, Australia and the Neotropics to establish any genetic differences which might affect the effectiveness of biological control.

4. Screening of potential fungal biological control agents against Ethiopian *Parthenium* to check pathogenicity.

5. Any appropriate testing of host specificity of potential biological control agents on critical species of plants not tested for Australia or India.

6. Selection of natural enemies for introduction into Ethiopia, preparation of dossiers, and request permission to introduce.

7. Decisions to introduce, study further aspects of safety, or not to introduce.

8. Further studies if required under #7.

9. Introduction and culture, followed by release of approved biological control agents.

10. Establishment, redistribution and monitoring of natural enemies.

11. Evaluation of impact of natural enemies through monitoring and a survey to compare with pre-programme survey.

Discussion and conclusions

As an exotic invasive weed, *Parthenium* can be expected to continue to expand its range until all suitable habitats are occupied. Efforts to contain it will at best delay this process. Impact on agriculture and human health (McFadyen 1995) will increase, and as the human population becomes sensitised, the medical effects are likely to escalate.

Biological control does NOT offer an instant solution, but the reports from Australia and India ARE sufficiently encouraging that it must make a major contribution to any management plan, and in the longer term may solve the problem. I offer the collaboration of my programme to develop a tripartite project initiative involving CABI, Queensland Department of Natural Resources and Ethiopia to address such a programme.

Development of national capability in weed biological control should then assist Ethiopia to address the problems of other alien invasive weeds, such as water hyacinth (*Eichhornia crassipes*), *Prosopis juliflora* and the parasitic weeds *Striga, Orobanche* and *Cuscuta*.

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Principles and prospects for integrated weed management in the wheat production systems of Ethiopia

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Abstract

The principles of integrated weed management (IWM) have been applied to weed control research conducted by the national wheat research program of Ethiopia since the mid 1980s. This paper presents case studies of wheat-based, IWM-oriented research in Ethiopia, focussing on how weed interference can be minimized by changes in crop management practices such as crop rotation, tillage methods, crop residue management, and soil fertility measures. For specific problematic weed species, economic threshold weed densities have been determined across a range of prices for inputs and outputs. An ox-drawn row-seeder has been developed in Ethiopia to facilitate the placement of wheat seed and basal fertilizer in rows, thereby facilitating manual or mechanical in-crop weed control.

Introduction

The management of weeds is an essential aspect of maintaining crop productivity within an economically viable and ecologically sustainable agricultural system. Adopting a "systems approach" implies that weed management, as a component of the agricultural system, must be considered in terms of the complex interactions among social, economic and environmental factors. Weed management strategies cannot be developed in isolation if they are to be effective and relevant to farmers, extension personnel, agro-industry, policy makers, and the consumer.

Integrated weed management (IWM) constitutes a systems approach. Globally, IWM incorporates aspects of the following agronomic practices into strategies capable of reducing weed interference while maintaining acceptable crop yields (29):

- crop rotation practices;
- soil nutrient and fertilizer management;
- plant breeding for enhanced competitive ability;
- mechanical weed control;
- chemical weed control; and

- tillage and crop residue management.

IWM is a weed management system designed to be economically, environmentally, and socially acceptable. IWM is a subset of the applied agricultural systems (27) identified variously as:

- integrated pest management (IPM);
- sustainable agriculture;
- integrated farming systems;
- alternative agriculture; and
- best management practices.

The principal foci of this paper are threefold:

1. to highlight the conceptual framework of IWM, drawing primarily on specific research themes incorporated in the national wheat research program of Ethiopia;
2. to emphasize, using the same specific examples, that research on weed control in wheat in Ethiopia, as a sub-component of general wheat agronomic research, has increasingly adopted an integrated approach since the mid 1980s; and
3. to present some of the potential applications of the results arising from such research into IWM approaches in the wheat crop in Ethiopia.

IWM and crop rotation practices

Crop rotations are an important part of IWM and the more diverse the species included in the rotation, the more likely that the rotation will facilitate control of indigenous weed species. Nonetheless, one cycle of crop rotation may not necessarily affect weed interference and alter weed species composition. Thus, longer-term studies are necessary to examine the effects of crop rotation on weed population dynamics.

Most crop scientists in Ethiopia have been exposed to one or more of the multi-disciplinary papers arising from the long-term wheat-based crop rotation trials implemented by the national wheat team at the Kulumsa and Asasa stations (3, 6). These trials were initiated in 1992, and have been designed to examine the complex interactions of crop rotation sequences (i.e., 2 and 3 year rotations of wheat with faba bean, rapeseed, and barley) with constant annual rates of application of fertilizer N and P.

The effects of crop rotation and fertilizer application on the density and biomass of the predominant weed species at the mid-tillering stage of the wheat crop are summarized in Tables 1 and 2 for the Kulumsa and Asasa trials in 1996,

Table 1. Effect of crop rotation and fertilizer application on weed density[a], weed biomass (g/m^2), and wheat grain yield (kg/ha) at Kulumsa, 1996.

	Set.[b]	*Comm.*	*Corr.*	*Poly.*	*Anag.*	Total broadleaf density	Weed biomass	Wheat grain yield
Rotation	**	***	*			**	***	***
Dicot vs. cereal	*	**				0.10	**	***
2 vs. 3 year					*			
W#1 vs. W#2		*	***			*		
Fb vs. Rp		*			*		*	***
Nitrogen		*	0.10			*	**	***
Phosphorus	**	**				*	**	0.10
N x P								
Rot. x N				0.10				***
Rot. x P					0.10			
Rot. x N x P					0.10	*		
C.V.(%)	36.0	32.3	32.9	31.5	45.7	19.3	39.1	7.7

*, **, *** significant at P = 0.05, 0.01 and 0.001, respectively.

[a] transformed by square root of (weed count/m^2 + 0.5).

[b] *Setaria pumila, Commelina africana, Corrigiola littoralis, Polygonum nepalense, Anagalis arvensis.*

Source: (6).

Table 2. Effect of crop rotation and fertilizer application on weed density[a], weed biomass (g/m^2), and wheat grain yield (kg/ha) at Asasa, 1996.

	Set.[b]	*Corr.*	*Amar.*	*Galin.*	*Tag.*	Total broadleaf density	Weed biomass	Wheat grain yield
Rotation	*	*	*	0.10	0.10	*	*	***
Dicot vs. cereal	***		*				*	***
2 vs. 3 year		*				0.10		*
W#1 vs. W#2				*	**			***
Fb vs. Rp		***	**	*		**		*
Nitrogen						*		***
Phosphorus		***	*	***		0.10	***	*
N x P								
Rot. x N				0.10				
Rot. x P	*	*					0.10	
Rot. x N x P								
C.V.(%)	46.3	42.4	31.7	41.6	46.6	21.5	55.0	10.6

*, **, *** significant at P = 0.05, 0.01 and 0.001 respectively.

[a] transformed by square root of (weed count/m^2 + 0.5).

[b] *Setaria pumila, Corrigiola littoralis, Amaranthus graecizans, Galinsoga parviflora, Tagetes minuta.*

Source: (6).

respectively. For comparison, the effects of crop rotation and fertilizer on wheat grain yield are shown on the respective tables.

Summarizing the effects of rotation and fertilizer on the seven weed parameters presented for each of the two trials (Tables 1 and 2) indicates the frequency of significance for each specific effect (i.e., out of a total opportunity for 14 significant effects):

Overall rotation effect	12
Wheat in dicot vs. cereal-based rotation	7
Wheat in 2 vs. 3 year rotations	3
Wheat #1 vs. #2 following any precursor	5
Wheat following faba bean vs. rapeseed	7
N effect (30 vs. 60 kg/ha)	5
P effect (0 vs. 20 kg/ha)	9

Thus, crop rotation and annual N and P fertilizer application rates had significant effects on the densities of individual weed species and on total weed biomass at both sites in 1996. Wheat in dicot-based rotations exhibited a marked reduction in both grass and broadleaf weed densities and weed biomass in contrast to wheat in continuous cereal rotations. Similarly, the second wheat crop after any precursor crop was more heavily infested with weeds than was the first wheat crop (i.e., immediately subsequent to the break crop). Thus, short cycle rotations of wheat with either dicot crop used in the current study (i.e., faba bean and rapeseed) would be beneficial from the perspective of minimizing weed populations and weed competition with wheat.

In some instances, weed species responded to treatments differentially across sites. For example, at Kulumsa, wheat after faba bean exhibited a reduced weed population in comparison with wheat after rapeseed, while at Asasa, rapeseed appeared to reduce weed densities in the succeeding wheat crop(s) to a greater extent than faba bean.

By way of introduction to an extremely threatening weed species as far as wheat production in Ethiopia is concerned, crop rotation has a marked effect on grass weed species in the *Bromus* genus. Continuous cereal production greatly exacerbates the problem of *Bromus* spp. in continuous small grain production systems, both in Ethiopia (3) and globally (21). Currently, brome grass, *Bromus pectinatus*, is expanding rapidly across the bread wheat belt of southeastern Ethiopia: a mean density of 320 plants m^{-2} of brome grass has been observed in wheat crops in Asasa zone (17).

As one component of the crop rotation theme, double cropping was studied on-station at Sinana in southeastern Ethiopia (37). Under the ambient bimodal rainfall conditions and compared to the traditional farmers' practice of fallowing land during one season, double cropping increased total grain output and net income. The best crop combination, both in agronomic and economic terms, consisted of field pea grown during the first season followed by bread wheat in the second season. Currently, the double cropping technology is being tested in a multi-location on-farm trial in several districts in Bale. The authors of the published report (37) postulated that double cropping in this bimodal rainfall zone could minimize several negative aspects of the traditional fallow system:

1. soil erosion could be reduced by maintaining a crop vegetative cover in both seasons;
2. the rate of expansion of cultivation onto pasture land could be reduced by intensifying production on the currently cropped areas;
3. weed control could be facilitated by rotating non-cereal crops with the second season wheat crop; and
4. human and ox labor could be utilized more efficiently in a double cropping system than in a fallow-wheat system.

IWM and soil nutrient and fertilizer management

Since the application of plant nutrients to soil, especially fertilizer N, alleviates a common limitation to crop (and weed) growth, many weed species have developed an inherent ability to effectively compete with crops for access to nutrients; often, weeds use nutrient availability as an environmental signal or cue to break seed dormancy (29). To counter these adaptive mechanisms of weeds, nutrient applications may be timed more precisely to coincide with periods of peak demand by the crop, or may be placed more precisely to limit the access of weed species to the nutrient (i.e., as commonly practiced in banding of fertilizer close to crop seed).

Wheat-based on-farm fertilizer trials conducted during 1988-90 throughout Ethiopia were examined intensively for any indication of "side effects" of applied fertilizer N and P (31). Data on wild oat (*Avena fatua*) panicle density at maturity of the wheat crop were combined for analysis across 5 sites: mean wild oat panicle densities for the trials ranged from 140 to 323 panicles m^{-2}.

The combined analysis indicated that fertilizer N markedly increased the density of wild oat panicles (Fig. 1), suggesting that *A. fatua* utilizes fertilizer N more effectively than wheat, thereby exhibiting enhanced competitiveness with the crop under high N conditions. In this study, wild oat density in wheat was increased significantly by as little as 20.5 kg N ha^{-1}. The quadratic nature of the N response was apparent in that the maximum effect occurred at about 41 kg N ha^{-1}.

Conversely, the highest rate of fertilizer P decreased wild oat panicle densities at 4 of the 5 sites, all of which exhibited greater wheat yield response to P than to N. The P effect was significant in the combined analysis. This competitive

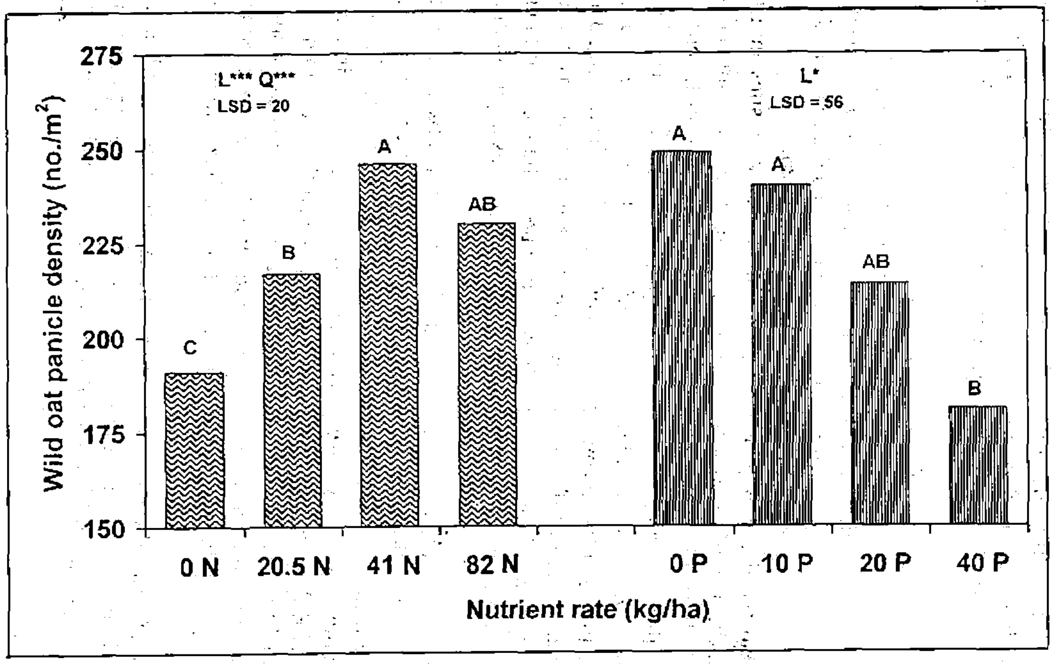

Figure 1. Effect of fertilizer N and P levels on *Avena fatua* panicle density at maturity of bread wheat.
Source: (31)

reduction in wild oat panicle density was presumably the result of an increase in early crop vigor (i.e., based on visual assessment) and a significant increase in total crop biomass. Furthermore, this result suggests that wild oats may be less responsive to P than bread wheat under field conditions.

In the same study, the impact of fertilizer on early broadleaf weed growth was reflected in the labor requirement for 2 hand weedings (i.e., at 30 and 45 days post-sowing) measured at 4 sites in the Adet zone. Fertilizer N applied at the rate of 138 kg N ha^{-1} increased hand weeding labor relative to the check (Table 3), attributable primarily to an increase in broadleaf weeds (i.e., since laborers are not able to reliably identify most grass weed species in a broadcast wheat crop). In this study, all of the N fertilizer was broadcast at sowing which probably stimulated an early flush of weed growth. Since split application of fertilizer N has usually been found to exert a positive or neutral effect on wheat grain yield in Ethiopia, splitting the N application should be recommended for small-holders, thereby:

- minimizing weed competition,
- reducing the requirement for hand weeding, and
- simultaneously reducing economic risk levels (i.e., the farmer would not apply the N top-dressing until assured of good emergence and growing conditions).

Broadleaf weed seedling densities were measured at 3 sites in 1989 at 30 days post-emergence of the wheat crop (i.e., prior to hand weeding and top-dressing of N). In Bekoji, 13.7 kg N ha^{-1} broadcast at sowing was sufficient to stimulate the germination of broadleaf weed seedlings (Table 4). The quadratic nature of the response indicated that higher levels of N could have been inhibitory to weed germination. In Gonde zone, N had no effect on broadleaf weed density. Fertilizer P decreased broadleaf weed seedling densities in a linear fashion in Gonde. This reduction in weed numbers may have been due to the increase in early crop vigor and biomass production with added P. No P effect was apparent in Bekoji zone.

The long-term effects of continuous N application observed within the wheat-based crop rotation trial at Kulumsa and Asasa (Tables 1 and 2) contrasted with the results generated by the on-farm N and P rate study (6, 31). Higher rates of N application did not increase weed density or weed biomass; in fact, in those cases where N did exert a significant effect, N reduced the measured weed parameters. Presumably, this observation reflects an additional benefit of split-application of N fertilizer as practiced in the crop rotation trial (i.e., as opposed to applying all N at sowing as in the previous study where N exacerbated weed problems).

Although basal P application had a minimal effect on the wheat crop parameters across both sites of the crop rotation study, relative to the effect of N, P fertilizer exerted a greater effect on weed parameters than did N (Tables 1 and 2).

Table 3. Effect of fertilizer N levels on the labor requirement for hand weeding.

Fertilizer ($kg\ ha^{-1}$)	Hand weeding labor (work-days ha^{-1} for two weedings)
0 N	88.4 B
46 N	92.3 AB
92 N	106.6 AB
138 N	111.5 A
$LSD_{0.05}$	19.5
Significance[a]	L**
Mean	99.7
C.V.(%)	27.5

[a] Only N main effect was significant: L = linear component.
Means within a column followed by the same letter do not differ significantly at the 5% level of the LSD test.
** Significant at the 1% level of probability.
Source: (31).

Table 4. Effect of fertilizer N and P levels on broadleaf weed seedling densities in wheat at 30 days post-emergence.

Fertilizer (kg ha^{-1})	Broadleaf weed density (seedlings m^{-2}) Gonde	Bekoji
0 N	238	509 B
6.8 N	263	568 AB
13.7 N	244	652 A
27.3 N	254	601 AB
$LSD_{0.05}$	NS	140
Significance (N)[a]	NS	Q*
0 P	285 A	548
10 P	244 AB	651
20 P	236 AB	553
40 P	233 B	578
$LSD_{0.10}$	51	NS
Significance (P)[a]	L*	NS
Mean	250	583
C.V.(%)	24.4	23.8

[a] Within experiments only N and P main effects were significant: L = linear and Q = quadratic components.

Means within a column followed by the same letter do not differ significantly at the 5% or the 10% level of the LSD test at Bekoji and Gonde, respectively.

* Significant at the 5% level of probability.

Source: (31).

Regarding weed densities, most (but not all) species were reduced in the plots receiving an annual application of 20 kg P/ha. However, at both sites, total weed biomass was increased by P. The logical interpretation is that the growth of individual weeds was sufficiently enhanced by P to more than counteract the effect of reduced weed densities.

The effects of competition among four bread wheat cultivars and four *A. fatua* densities on N and P uptake and utilization in grain and biomass were assessed in a field study in southeastern Ethiopia (33). Total N uptake by the mixed canopy of wheat and *A. fatua* varied among the wheat cultivars and increased linearly in response to wild oat density, while total P uptake only varied among wheat cultivars. The mean proportion of total N, total P and total biomass contained in the wild oat fraction was 30.5, 31.9 and 25.1%, respectively, indicating that wild oat was more successful than wheat at utilizing available soil N and P.

While there is evidence in some industrialized countries that fertilizer usage has reached excessive levels and may pose a threat to both human health and the environment, judicious and efficient use of fertilizer in Ethiopia has the potential to dramatically increase wheat grain yields and increase the national level of self-sufficiency for wheat grain. Ensuring adequate P nutrition of the wheat crop is an important component of IWM: by enhancing early crop vigor, P fertilizer can increase the ability of a wheat crop to competitively suppress several weed species. Since higher rates of N fertilizer could exacerbate weed density and the concomitant labor requirement for hand weeding, split application of N should be recommended to minimize economic risk and weed problems for peasant farmers. Peasant farmers should also have access to improved weed control technology as part of the wheat "production package" in order to realize the full benefits of the fertilizer input.

IWM and plant breeding for enhanced competitive ability

Production of crop species and cultivars that are better competitors with weeds is an important component of IWM. In general, crops that can germinate, root, emerge, and establish a dense leaf canopy earlier and faster are more likely to compete strongly with weeds.

Differences in the inherent ability of Ethiopian bread wheat cultivars to compete with wild oats have been reported (9, 35, 36, 39). In the first study (35, 36), the grain yield of each cultivar was linearly related to wild oat density, and the slopes of the individual regression lines ranged from -11.0 to -31.8 (kg/ha)/(wild oat seedling/m^2). Comparing the slopes, the semi-dwarf Dashen was significantly more susceptible to wild oat competition than ET13, Enkoy, or Israel, while the latter three cultivars did not differ from each other.

Wild oat seed yields varied in response to competition exerted by specific wheat cultivars (Fig. 2). At all *A. fatua* densities, Dashen allowed the highest level of wild oat seed production, Israel and Enkoy the lowest, and ET13 occupied an intermediate position. Thus, bread wheat cultivars clearly differ in their ability to suppress wild oat seed production. and this ability was relatively consistent across the range of wild oat densities. Wild oat panicle density in this study also varied in response to wheat cultivars (Fig. 2). It is of interest to note that the cultivars Enkoy and Israel, which resulted in the lowest wild oat seed yields, did not apparently have a similar effect in suppressing wild oat panicle production per unit area. However, the number of wild oat seeds panicle^{-1} was significantly lower as a result of the competitive effects of Israel and Enkoy relative to ET13 and Dashen, while ET13 and Enkoy markedly reduced the size of wild oat seeds (Fig. 3). Data from multi-location on-farm fertilizer trials conducted during 1996-97 suggest similar differences in competitive ability among the bread wheat cultivars released during the mid 1990s. In Asasa zone, plots sown to Qubsa (= HAR1685, a semi-dwarf bread wheat cultivar) exhibited 51 plants m^{-2} of brome grass at maturity of the wheat crop; in contrast, only 19 brome grass plants were recorded in plots sown to Mitike (= HAR1709, a tall bread wheat cultivar) (9).

Competition effects of three broadleaf weed species (*Guizotia scabra*, *Amaranthus retroflexus*, and *Galium spurium*) on the grain yield of three bread wheat cultivars were studied at Ambo (39). The three wheat varieties differed significantly in height as follows:

HAR1685 (84 cm) < HAR604 (95 cm) < HAR1709 (103 cm).

Among the three broadleaf weed species, *G. scabra* exerted the greatest effect on wheat grain yield. Wheat yield reductions at the maximum broadleaf weed seedling density of 160 seedlings/m^2 were 47.8, 29.6 and 18.6% for *G. scabra*, *A. retroflexus*, and *G. spurium*, respectively.

Wheat yield (Y) data (kg ha^{-1}) were fitted to a rectangular hyperbola model to facilitate the prediction of wheat grain yield loss, and to derive economic thresholds for herbicidal intervention in relation to weed seedling density as described by Taye and Tanner (38). The formula used for the rectangular hyperbola model follows:

$$Y = ywf\,[1 - Id/(100*(1+Id/A))]$$

where ywf = yield (kg ha^{-1}) in the absence of weeds,
A = percentage yield loss as weed density approaches infinity,
I = percentage yield loss per unit of weed density as the density approaches zero, and
d = weed density in number m^{-2}.

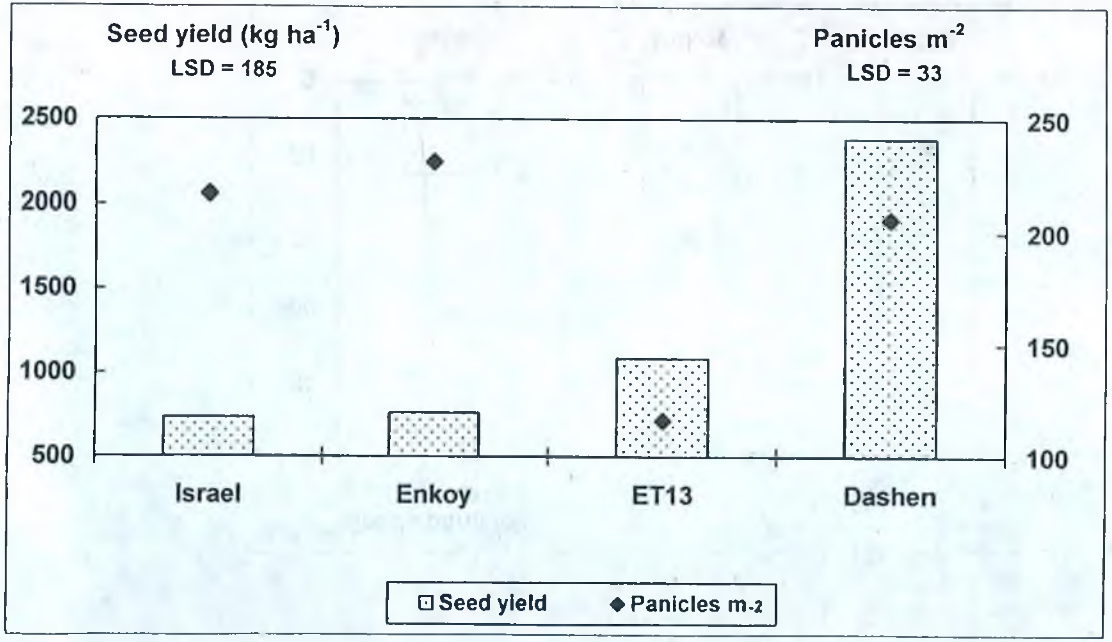

Figure 2. The effects of four Ethiopian spring bread wheat cultivars on wild oat seed yield and panicles m^{-2}.
Source: (36)

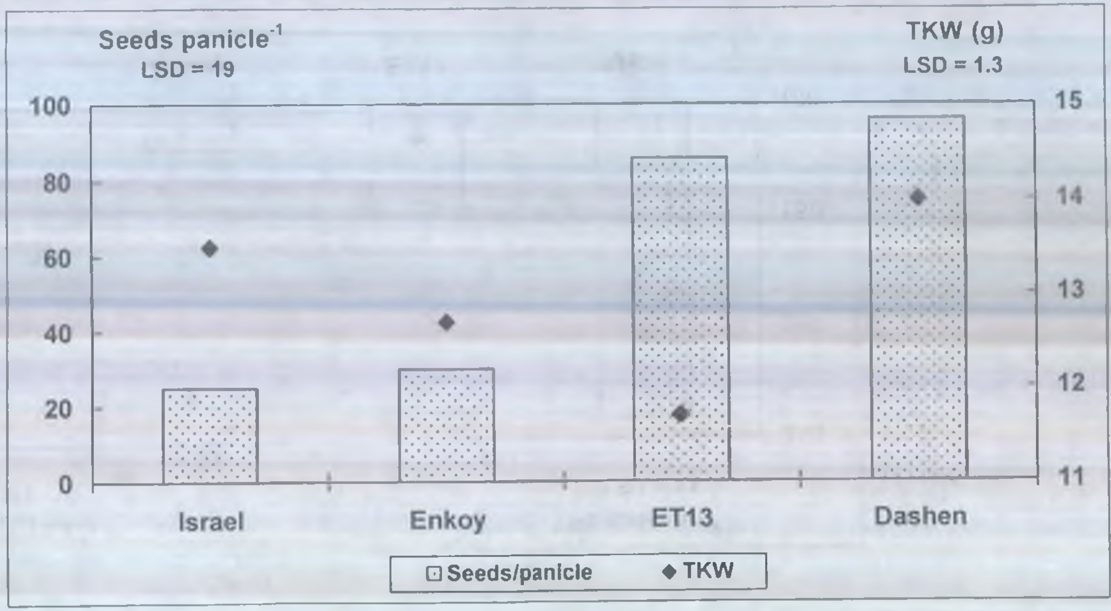

Figure 3. The effects of four Ethiopian spring bread wheat cultivars on wild oat seeds panicle^{-1} and thousand kernel weight. Source: (36).

The hyperbolic equation, expressing grain yield loss (YL) in kg ha^{-1} is:

$$YL = ywf[Id/(100*(1+Id/A))].$$

The resulting R^2 values (Table 5), ranging from 0.824 to 0.999, indicate that an adequate fit was obtained for all data sets. The relative rankings of "A" and "I" for the three weed species (Table 5) indicate that *G. scabra* is generally more competitive with wheat than *A. retroflexus*, while *G. spurium* appears to be the least competitive.

Figure 4 presents a graphical comparison of the "goodness-of-fit" of the rectangular hyperbola model for the three *G. scabra* by wheat variety combinations: the actual points lie close to the lines generated by the hyperbolic model. Differential cultivar responses to weed competition are also apparent from the graph (Fig. 4): HAR1685 appeared to be the least affected by competition from this weed species.

During 1997, a multi-location on-station study was initiated to assess differences in grain yield (GY) potential, under conditions of high grass weed infestation in the field, among 20 genotypes of bread wheat previously selected for high GY potential under weed-free conditions (40). *Avena sativum* was used as a proxy for grass weeds. The GY of wheat varied from 982 to 1951 across the 20 genotypes and averaged across 3 locations. The two recently-released cultivars HAR 1685 and HAR 604 were significantly higher yielding than all other entries in the trial with the exception of entry 19 (advanced line HAR 1918). At one site (Holetta), oat biomass yield was significantly and negatively correlated with wheat seedlings m^{-2} (WSM), wheat biomass at tillering and anthesis, and wheat GY. This suggests that higher initial wheat seedling stands and more productive canopies for specific wheat genotypes facilitated the suppression of wild oat biomass production. Similarly, the density of oat panicles m^{-2} at maturity was negatively affected by WSM, wheat spikes m^{-2} at maturity, and wheat biomass at tillering and anthesis.

Wheat breeders in Ethiopia should use all available information regarding the competitive ability of wheat genotypes with weeds, and the associated agronomic traits related to competitive ability, when planning their crossing and selection activities.

In passing, it is important to note that biotechnology is currently providing the global research community with options to radically alter crop species by introducing genetic systems from other taxonomic groupings. Genes have been introduced to several cultivars of cultivated crop species to impart resistance to broad spectrum, environmentally-friendly herbicides such as glyphosate, thereby facilitating lower cost, integrated weed control. In many crop species, issues of biosafety may constrain the practical application of such novel technologies, particularly in cross-pollinated crops such as maize, sorghum and the *Brassica*

Table 5. Parameters of the rectangular hyperbola model fitted to wheat grain yield data from the broadleaf weed competition trial (Ambo, 1997).

Weed species	Wheat cultivar	Ywf ($kg\ ha^{-1}$)	A (%)	I ($\%\ m^2\ plant^{-1}$)	R^2
A. retroflexus	HAR 604	4607	42.6	1.095	0.99
	HAR 1685	3410	71.7	0.371	0.99
	HAR 1709	4257	50.0	0.264	0.99
G. scabra	HAR 604	4761	74.4	1.092	0.95
	HAR 1685[a]	3476	100.1	0.596	0.96
	HAR 1709	4533	87.0	0.865	0.89
G. spurium	HAR 604	4131	82.5	0.150	0.98
	HAR 1685	3156	39.6	0.213	0.98
	HAR 1709	4432	24.9	0.427	0.82

n = 6 for each species by cultivar data set.
[a] n = 5 for this species by cultivar data set.
Source: (39).

Table 6. Treatments used in the on-farm evaluation of the row seeder (Gonde/Itheya, 1995).

Treatment	Seeding method	Weed control method
1	RS[a]	HW
2	RS	RW + SHW
3	RS	CHEM
4	BC	HW
5	BC	CHEM
6	BC	2,4-D

[a] RS = "AIRIC Row Seeder"; BC = broadcast seed and basal fertilizer and incorporate with ox plow; HW = hand weeding at 25-30 days after emergence (DAE); RW = Madagascar row weeder at 25-30 DAE; SHW = supplementary hand weeding at 5-10 days after row weeder; CHEM = fenoxaprop-P-ethyl at 69 g a.i. ha^{-1} applied at 20-25 DAE and 2,4-D at 720 g a.i. ha^{-1} applied at 25-30 DAE; 2,4-D = 2,4-D at 720 g a.i. ha^{-1} applied at 25-30 DAE.
Source: (10).

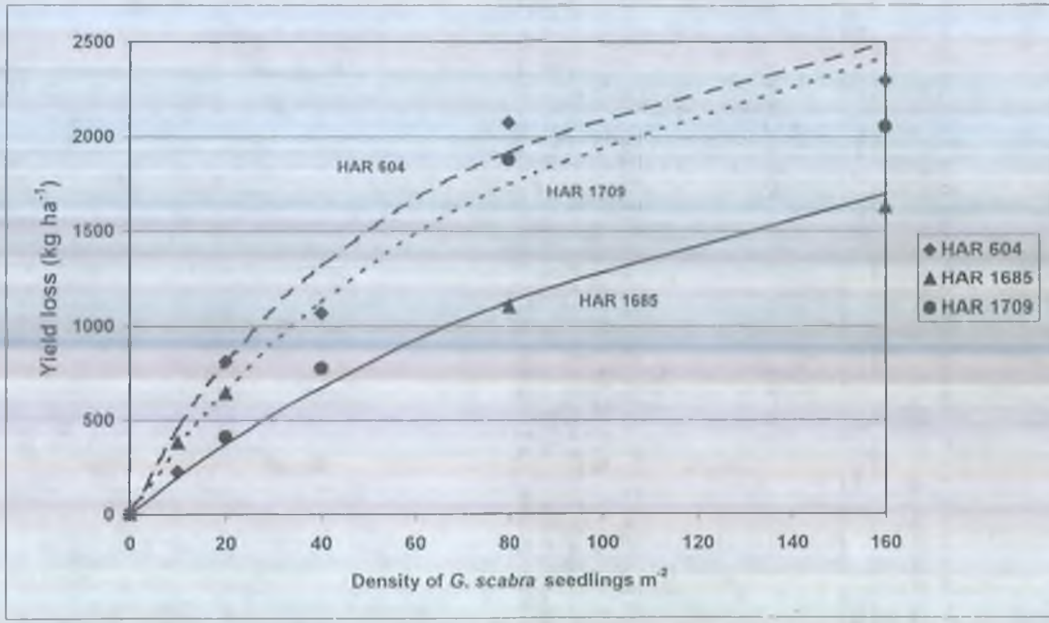

Figure 4. Grain yield loss as a result of competition from *Guizotia scabra* on three bread wheat cultivars at Ambo PPRC, 1997. Source: (30)

species. For example, a Danish study has shown that herbicide-resistant rapeseed passed on its resistance to weedy *Brassica* spp. in two generations. However, since wheat is self-pollinated, and not commonly grown in intimate association with weed species capable of forming viable hybrid progeny, the risk of such gene escape in wheat is minimal.

IWM and mechanical weed control

Cultural weed control methods studied by CADU and ARDU research staff during the 1960s and 1970s included hand weeding, the use of high seed rates, stale seedbed preparation methods, minimum tillage practices, the use of a mechanical weeder, and the interaction of weed control with variety and fertilizer usage (32). However, weed control recommendations issued to peasant farmers during those decades consisted exclusively of advice on the timing of hand weeding and the use of phenoxy herbicides for the control of broadleaf weeds in wheat (32).

In Ethiopia, broadcasting wheat seed and fertilizer and incorporating both with the local ox-plow ("maresha") is the common practice for peasant farmers. This traditional practice can result in poor crop stands, particularly for some semi-dwarf wheat cultivars with relatively short coleoptiles, as seed is buried at variable depths in the upper layers of the soil. Farmers often adopt higher than recommended seed rates to alleviate this problem and to enhance crop competition with weeds. Furthermore, some grass weeds resemble the wheat crop during early development stages, making it difficult for peasant farmers to effectively hand weed their broadcast wheat: yield losses due to grass weeds can be considerable, and total crop failure can occur, particularly in districts with a high incidence of *Bromus pectinatus*. Chemical control of grass weeds, using products such as Puma Super, is highly effective for most grass weed species (except *Bromus*), but the cost of using this chemical has been cited to be in the order of 330 EB/ha (24).

One approach to solving the problem of grass weeds in peasants' wheat fields is to sow the crop in rows so that all weeds appearing between rows can be more readily controlled either by hand pulling or by using an inter-row mechanical weeder.

To explore the feasibility of row seeding of wheat in Ethiopia, two small-scale implements, a row-seeder and a push-type inter-row-weeder, were introduced from Madagascar and tested in 1988. The implements were found promising in terms of reducing the labor required for weeding, and were subsequently entered into verification trials in 1989 and 1990 on farmers' fields and at Kulumsa R.C. in Arsi Region (2). The results indicated that there were no significant differences between the traditional practice and the row-based technology for most measured crop yield and phenological parameters. The combination of row-seeding and row-weeding reduced the labor required for weeding by up to 74% relative to the conventional farmers' practice. However, seeding wheat in rows significantly increased the labor required at sowing time, and, as a result, farmers rejected the trial technology package.

A novel implement, which presents tremendous potential for the application of IWM for wheat production, has been developed in Ethiopia, namely the "AIRIC Row Seeder for Wheat" (10). No ground wheels are employed in the design of the row seeder: seeds are metered by oscillating a lever in cycles corresponding to the footsteps of the operator. The seeder has been calibrated to release a predetermined amount of seed and fertilizer in every stroke and distribute the mixture uniformly among the four rows (spaced 25 cm apart) and along the distance covered by a single pace of the operator. The amount of seed and fertilizer released in each stroke is based on the recommended seed rate of 150 kg/ha (for row-sown wheat) and a basal fertilizer application of 100 kg/ha of diammonium phosphate (DAP). Additional N can be supplied as required from top-dressed urea fertilizer.

The row seeder was tested in 5 farmers' fields in the Kulumsa vicinity during 1995 (Table 6). In the 1995 trial, the row seeder markedly improved the efficiency of labor required to sow wheat, using only 22% of the time per unit area compared to the farmers' conventional practice (Table 8). Surprisingly, the reduction in labor required for hand weeding as a result of row seeding was not as great as could logically be expected (i.e., comparing T1 and T4); nonetheless, the use of the inter-row weeder markedly reduced hand weeding labor (i.e., comparing T2 and T4). The total labor required for all operations varying among the six treatments ranged from a low of 1.28 work-days ha^{-1} (for T3 = row seeder + complete chemical weed control) to the maximum of 22.08 (for T4 = broadcast + hand weeding). Although labor for harvesting the wheat crop was not included in the economic analysis, row seeding reduced labor for this activity by 9% (4.25 for broadcast vs. 3.79 work-days ha^{-1} for row seeded wheat).

During 1996, the row seeder was tested in 5 farmers' fields in the Asasa vicinity, where *Bromus* is more problematic, and the treatments were modified (Table 7) to reflect observed limitations in the 1995 trials. All plots sown by the row seeder were harrowed once using a blade harrow attachment (also developed by the staff of AIRIC) on the row seeder frame immediately prior to seeding; this pre-seeding operation eliminated newly emerged weed seedlings on the "stale" seedbed (cf. the conventional practice in which the post-seeding pass with the ox plow to incorporate seed and fertilizer destroys such seedlings). In 1996, the total time required for row seeding (i.e., the sum of 0.54 work-days ha^{-1} for the blade harrow and 0.81 work-days ha^{-1} for the row seeder) represented 38% of the time required for conventional sowing by broadcasting. Labor requirements for hand weeding, row weeding and herbicide application were similar to the values measured in 1995. Total labor requirements ranged from 15.66 to 26.66 work-days ha^{-1}.

In the MRR analysis of the 1995 trials (Table 9), the highest cost treatments, T5 and T3, were dominated by treatment T2. Thus, treatments in which complete chemical weed control (i.e., fenoxaprop-P-ethyl + 2,4-D) substituted for more labor-intensive weed control technologies were not profitable, particularly considering the relatively low density of grass weeds encountered at the trial sites in 1995. The most profitable treatment was T2 (= row seeder + row weeder + supplementary hand weeding), incurring 35.59 EB ha^{-1} in additional variable costs relative to T6 and realizing an increase of 418.27 EB ha^{-1} in net benefit (= 1175% rate of return on the investment).

Table 7. Treatments used in the on-farm evaluation of the row seeder (Asasa, 1996).

Treatment	Seeding method	Weed control method
1	BC[a]	2,4-D + SHW
2	RS	2,4-D + SHW
3	RS	RW + SHW

[a] BC = broadcast seed and basal fertilizer and incorporate with ox plow; RS = "AIRIC Row Seeder"; 2,4-D = 2,4-D at 720 g a.i. ha^{-1} applied at 25-30 days after emergence (DAE); RW = Madagascar row weeder at 25-30 DAE; SHW = supplementary hand weeding at 35-40 DAE. Source: (10).

Table 8. Summary of labor (work-days ha^{-1}) used in each operational component of the treatments in the row seeder trials.

Treatment	Row seeding	BC[a] and cover with ox plow	Hand weeding	Row weeding	Herbicide application	Total labor
Gonde/Itheya 1995						
1[b]	0.83	-	17.04	-	-	17.87
2	0.83	-	11.77	3.59	-	16.19
3	0.83	-	-	-	0.45	1.28
4	-	3.85	18.23	-	-	22.08
5	-	3.85	-	-	0.45	4.3
6	-	3.85	-	-	0.23	4.08
Asasa 1996						
1[c]	-	3.56	14.39	-	0.24	18.19
2	1.35[d]	-	14.07	-	0.24	15.66
3	1.35[d]	-	20.95	4.36	-	26.66

[a] BC = broadcast seed and basal fertilizer.
[b] See Table 6 for treatment definitions for 1995 trials.
[c] See Table 7 for treatment definitions for 1996 trials.
[d] Comprising 0.54 for preceding blade harrow operation and 0.81 for row seeder operation.
Source: (10).

Table 9. Marginal rate of return analysis of the treatments in the row seeder trials.

Rank	Treatment	Net benefit ($EB\ ha^{-1}$)	Total variable costs ($EB\ ha^{-1}$)	Marginal net benefit ($EB\ ha^{-1}$)	Marginal variable costs ($EB\ ha^{-1}$)	Marginal rate of return (%)
Gonde/Itheya 1995						
1	5 BC + CHEM[a]	2840.01	587.10	D[c]	3.31	D
2	3 RS + CHEM	2842.73	583.79	D	296.09	D
3	2 RS + RW + SHW	3293.44	287.70	99.12	4.59	2159
4	4 BC + HW	3194.32	283.11	106.74	8.66	1233
5	1 RS + HW	3087.58	274.45	212.41	22.34	951
6	6 BC + 2,4-D	2875.17	252.11			
Asasa 1996						
1	3 RS + RW + SHW[b]	4136.98	334.81	64.26	20.31	316
2	1 BC + 2,4-D + SHW	3135.98	315.61	D	D	
3	2 RS + 2,4-D + SHW	4072.72	314.50			

[a] See Table 6 for treatment definitions for 1995 trials.
[b] See Table 7 for treatment definitions for 1996 trials.
[c] Dominated by next lower ranked non-dominated treatment (i.e., higher cost and lower net benefit than next lower ranked treatment).
Source: (10).

In the MRR analysis of the 1996 trials (Table 9), the broadcast treatment (T1) was dominated by the lowest cost treatment T2 (i.e., T1 cost more and returned less revenue than T2). The most profitable treatment T3 (= row seeder + row weeder + supplementary hand weeding) incurred 20.31 EB ha^{-1} in additional variable costs relative to T2 (= row seeder + 2,4-D + supplementary hand weeding) and increased net benefit by 64.26 EB ha^{-1} (= 316% rate of return on the investment).

Farmers responded favorably in their comments on the performance and utility of the row seeder. They observed that wheat in the row seeded plots was superior to the broadcast crop in terms of stand establishment and plant vigor, particularly in the 1996 trials in Asasa zone, and attributed this to uniform distribution of the seed, enhanced emergence of wheat seedlings, and the placement of basal fertilizer in crop rows, thus enabling wheat to utilize the fertilizer more effectively while depriving weeds in the inter-row spaces of nutrients. They noted that the row seeder worked effectively in rough and cloddy fields, applying a uniform rate of seed and fertilizer. Hand weeding was reported to be easier in row seeded vs. broadcast wheat, and it was also possible to use the row weeder (having a 17 cm wide blade) between the rows. However, farmers expressed a concern that use of the row weeder might be limited on heavier clay soils, particularly when the soils are saturated.

Thus, the row seeder represents an important breakthrough in IWM technology for peasant wheat farmers in Ethiopia. At present, the row seeder is being demonstrated by extension personnel at selected sites throughout Arsi Region.

IWM and chemical weed control

Research into chemical weed control in wheat began in Ethiopia during the late 1960s (32). Initially, low priority was given to screening alternate broadleaf herbicides in the first decade of research, since the available phenoxy compounds provided adequate control. Subsequent to the shift in the weed spectrum towards phenoxy-tolerant broadleaf species and grass weeds, a greater number of broadleaf and grass herbicide screening activities were conducted in the early 1980s.

On-station herbicide screening trials in Ethiopia (16, 19, 26, 28) have focussed on identifying high efficacy weed control chemicals. In every case, herbicide trial data have not been subjected to economic analysis, since there are often no market prices available, in Ethiopia, for the majority of the experimental products. Such on-station herbicide response data has been augmented by observations of weed biology, such as weed species emergence patterns (15), and in-crop weed surveys (17).

During the mid 1980s, high priority was given to testing weed control technologies, including chemical and manual control, on farmers' fields (1, 7, 11, 24, 34), and to subjecting the data to a rigorous economic analysis (i.e., considering the sensitivity of the recommended technology to changes in prices of inputs and outputs). One study, conducted during 1988 and 1989 to assess the effects of Brittox and Illoxan on weed-infested farmers' wheat fields, established that under conditions of high weed competition, the herbicides were economically superior to hand weeding even at triple the concurrent official herbicide prices (34). Another study, in the Adet zone, established that the highest on-farm grain yield and economic benefit, from among several alternative technologies, was obtained from the application of 92-20 kg N-P/ha and 2,4-D on an improved bread wheat cultivar (11). In Sinana district, wheat response to four crop management factors, including weed control, was observed to differ markedly between farmers' fields and the research station (4): apparently station conditions differed dramatically from farmers' circumstances – an observation that has obvious implications for the extrapolation of research results generated on station to the surrounding small-scale farming community. Thus, it was generally recognized that weed control research must incorporate a farming systems approach to adequately reflect farmers' biological and socio-economic circumstances.

A study of the cost of wheat production conducted by ILRI in Arsi Region during 1994 (13) underscored the limitations of blanket crop input recommendations sometimes put forth in extension packages. While wheat researchers had originally intended for application of the herbicide Puma Super to be dependent upon the density of grass weeds in the crop, the research package was interpreted more rigidly, resulting in sub-optimal economic efficiency when the expensive, imported herbicide was applied indiscriminately. To address this deficiency, IAR researchers conducted research to establish grass weed control thresholds that are economically acceptable, based on an explicit minimum marginal rate of return of 100% (38, 39, 41, 42).

The concept of threshold weed densities can be more readily grasped by relating the value of grain yield recovered as a result of herbicide application to weed seedling density (Fig. 5). Economic threshold levels for each weed species occur at the point of intersection with the weed control cost lines. As the cost of weed control is increased (i.e., the MARR scenario vs. the break-even level), the threshold increases, particularly for the less competitive grass weed species. One can note that the economic threshold density for a highly competitive weed species such as *Snowdenia polystachya* is markedly lower than that for the weak competitor *Phalaris paradoxa*.

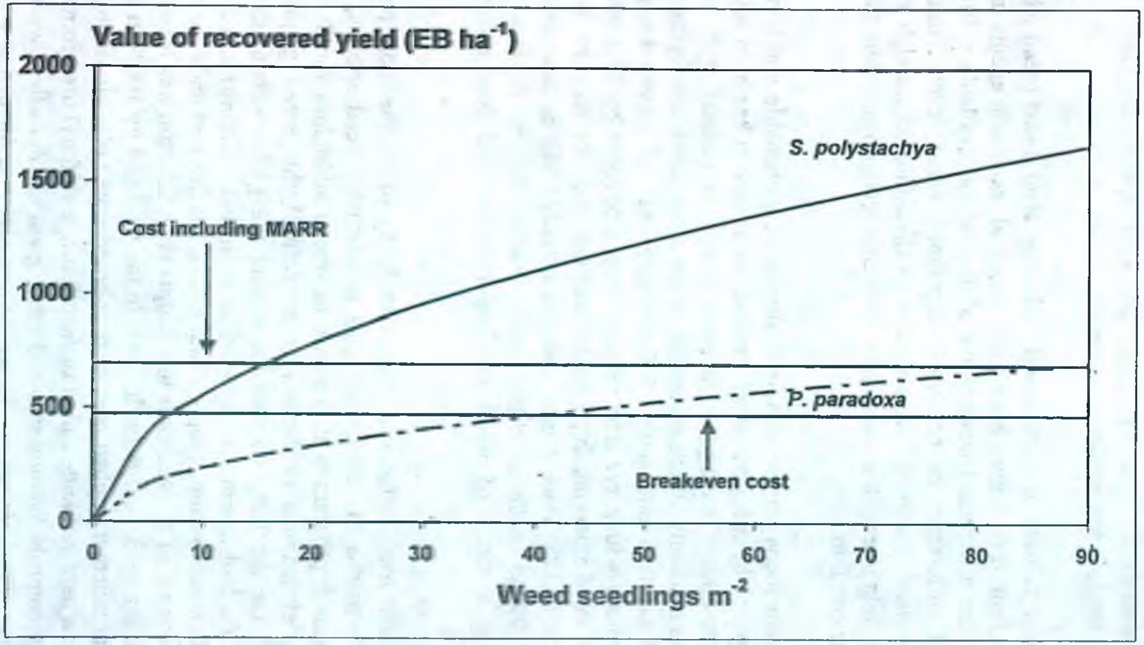

Figure 5. Value of recovered grain yield (EB/ha) of bread wheatd cultivar K6295-4A in relation to the cost of herbicidal control of two grass species.

Source: (42)

Similarly, specific economic weed threshold recommendations may be required for wheat cultivars differing in competitive ability. For example, the contrast between a semi-dwarf and three tall cultivars in one study was striking (42). Herbicidal weed control resulted in a much higher value of recovered grain yield in the semi-dwarf cultivar (Fig. 6), and threshold weed levels were correspondingly lower for the semi-dwarf.

As Ethiopian farmers are increasingly adopting semi-dwarf bread wheat cultivars to benefit from their higher grain yield potential, extension agents must be made aware of the differential competitive ability of the available cultivars and the associated difference in economic threshold weed levels. Information on economic weed threshold levels should be disseminated through the extension service to help agents fine tune their herbicide recommendations to reflect local agronomic conditions.

Let us again focus on the serious challenge to sustainable wheat production in Ethiopia posed by the grass weed *Bromus pectinatus*. It has been established that the relative time of emergence of grass weeds, in general, with respect to the wheat crop markedly affects the nature of the competitive interference imposed by the weed (43). In one study, 400 seedlings m^{-2} of downy brome emerging simultaneously with a rye crop reduced crop seed yield by 33% while the same density of weed emerging three weeks later than the crop reduced crop seed yield by only 10% (12). Thus, a new research initiative will be launched in Ethiopia during 1999 to establish wheat yield losses due to *Bromus* competition, considering a range of weed seedling densities and four relative times of emergence.

Although the row seeder intervention probably offers the most promising and sustainable means of controlling this problematic weed species, the national wheat research program will continue to screen herbicides for *Bromus* control. However, evaluations of herbicides to control this weed genus have been conducted for the last two decades around the globe without much apparent success (30). Metribuzin was reported to control *B. secalinus* and *B. tectorum* in wheat with a narrow application window (22), but this herbicide has not exhibited effective control of *B. pectinatus* in Ethiopia (14). Ethiozin was reported to reduce the population of *B. pectinatus* by 39% in the field and by 100% in a glass house experiment whether applied pre- or post-emergence (14). Monsanto has recently developed a new herbicide called sulfosulfuron, a sulfonyl urea compound, which selectively controls *Bromus* spp. and other grass and broadleaf weeds, including *Avena fatua*, *Phalaris minor*, *Anagallis arvensis* and *Medicago polymorpha*, in wheat (23, 25). A sample of this herbicide has been obtained for screening purposes in Ethiopia.

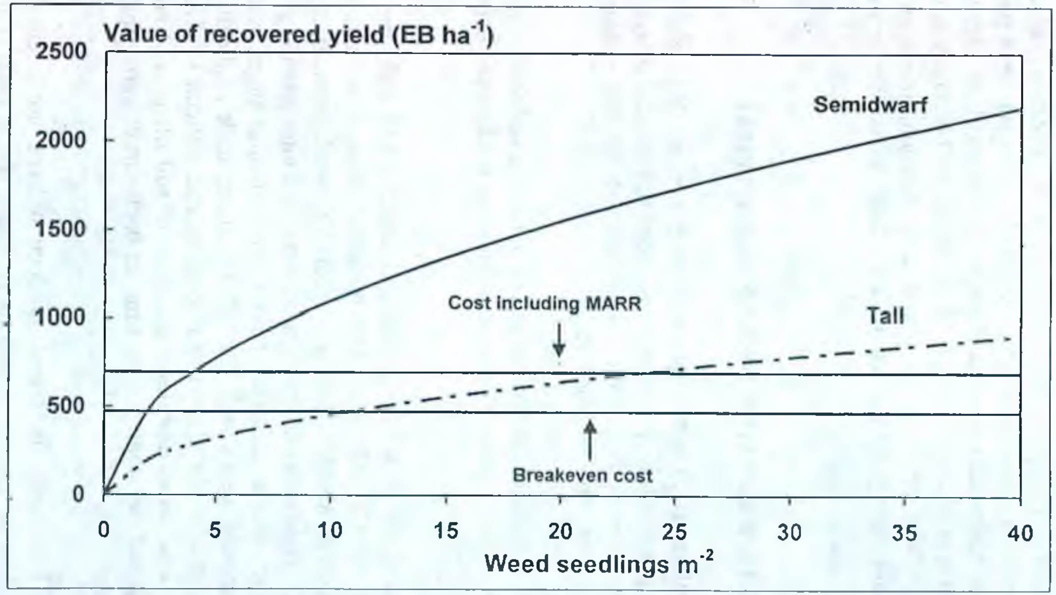

Figure 6. Value of recovered grain yield (EB/ha) of tall and semidwarf bread wheat cultivars in relation to the cost of herbicidal control of *Avena fatua* .

Source: (42)

Globally, the "super" weed phenomenon seems worrying. In several regions of the developed world, annual grass weed species, particularly in the genera *Avena*, *Hordeum*, *Lolium*, *Setaria* and *Phalaris*, have developed resistance to a broad range of chemically-related grass herbicides, including the Illoxan, Puma and Grasp herbicides with which most wheat researchers in Ethiopia are familiar. Recently, paraquat-resistant biotypes of *Hordeum glaucum* were reported in Australia – the first report worldwide of resistance to paraquat. The development of herbicide resistance does seem a particularly serious threat to sustainable wheat production, but this phenomenon will certainly emphasize the importance of IWM practices involving crop rotation, mechanical control, herbicide rotation, and good sanitation as the basis of economic weed control strategies.

IWM and tillage and crop residue management

Conservation tillage (CT) is an important component of IWM globally, and is defined as any practice (i.e., chisel plowing, ridge tilling, zone tillage, zero or no tillage) that leaves crop residue on at least 30% of the soil surface (29). The benefits of CT commonly cited include:

- reduced soil erosion;
- decreased surface runoff of pesticides and fertilizers; and
- maintenance of habitats supporting wildlife and beneficial fauna.

Despite the promotion of IWM as a means of reducing herbicide use, there have been concerns that CT will necessitate increased reliance on herbicides (29). However, CT often affects multiple aspects of weed population dynamics, including seed germination and emergence, intra- and inter-specific competition, and seed production and dispersal. Under some circumstances, retained crop residue may suppress weeds such that additional herbicide applications are not necessary. The effects of CT are often complex and difficult to predict. Thus, proposed modifications to traditional practices of soil tillage and crop residue management should be studied over time in each target agro-ecosystem and cropping system.

In Ethiopia, CT systems for wheat production have not been extensively researched, despite the extremely serious problem of soil erosion in highland regions. During 1989-90, a trial was conducted in Arsi Region consisting of a factorial arrangement of 4 mechanized and 4 ox-plow tillage systems (8). The results clearly indicated that, without sacrificing grain yield, glyphosate-based tillage systems reduced weed populations and the total labor required for wheat production. Grass weed density at 30 days p.e. was affected by tillage: conventional maresha tillage and minimum maresha tillage (based on glyphosate) had significantly lower densities of grass weeds, primarily *Setaria pumila* and *Digitaria abyssinica*, than the other tillage treatments. However, at the concurrent price levels in Ethiopia, the minimum tillage practice was not considered economical, but would have been if the price of glyphosate was reduced by 20%.

A long-term, multi-factor trial was initiated during 1992 at four sites in Arsi Region. This trial encompassed varied practices for crop stubble management (burning, partial removal, full retention), tillage (minimum, conventional), and cropping sequence (faba bean, rapeseed, or barley as precursors in 1992 vs. continuous wheat) under both mechanized and ox-plow tillage systems to assess the effects on weed population dynamics (20).

In this trial, stubble management significantly affected the density during 1994 of several broadleaf weed species. Stubble burning in the ox-plow system decreased the densities of the following broadleaf species:

- *Corrigiola littoralis* at Kulumsa
- *Guizotia scabra* at Bekoji
- *Galinsoga parviflora* at Asasa.

The density of *Amaranthus* spp. was reduced by complete straw retention in the mechanized trial at Kulumsa. Presumably, this observation reflects an allelopathic effect of wheat straw on seedlings of this weed species.

In the same study and season, the effects of tillage on broadleaf weed densities varied markedly across species and locations. The following broadleaf weeds exhibited significantly reduced densities under minimum tillage at one or more sites:

- *Corrigiolia littoralis*, *Guizotia scabra* and *Polygonum nepalense* at Bekoji
- *Amaranthus* spp., *Galinsoga parviflora*, and *Solanum nigrum* at Asasa
- *Polygonum nepalense* at the Gonde on-farm site

In a previous study conducted at Kulumsa, *Amaranthus* spp. exhibited poor germination on zero-till plots, and *Guizotia scabra*, *Galinsoga parviflora* and *Galium spurium* occurred at lower densities under zero-tillage compared to conventional tillage (15).

In this study, however, at the Kulumsa site during 1994, total broadleaf weed density was lower under conventional tillage in contrast to minimum tillage in both the mechanized and ox-plow systems. The following broadleaf weed species exhibited significant reductions in density under conventional tillage in the ox-plow system:

- *Galinsoga parviflora*
- *Corrigiola littoralis*

- *Galium spurium*
- *Solanum nigrum*

For some broadleaf weed species, the effects of interaction among the crop management factors exerted a significant effect on weed density. For example, in the mechanized trial at Asasa, the density of *Guizotia scabra* was increased by burning combined with conventional tillage in contrast to burning with minimum tillage; in stubble retained plots, the density of this weed was higher under minimum tillage.

During 1994 in the same study, the density of the problematic grass weed, *Bromus pectinatus*, was significantly reduced by stubble burning in several of the trials (Table 10). Experiments conducted abroad have indicated that stubble burning reduces the density of *Bromus diandrous* and also destroys seeds of *Avena fatua* (18). Weeds such as *Bromus* which thrive under the same cultural conditions as the wheat crop and possess a similar growth habit and morphology are difficult to remove by hand weeding and selective herbicides; thus, it may be necessary to utilize other methods, including occasional burning, to reduce the number of weed seeds in the soil. Conventional tillage also reduced *Bromus* density in the mechanized system at Bekoji and Asasa (Table 10). Repeated tillage brings weed seeds to the surface and exposes them to desiccation on one hand; tillage also buries seeds deep in the soil, creating unsuitable conditions for germination and growth, thereby reducing the density of some weeds. *Bromus* density in wheat in 1994 was consistently reduced by the use of dicot precursor crops in 1992, especially faba bean (Table 10). Higher infestations of the weed were observed in continuous wheat- and barley-based cropping sequences.

Interaction effects on *Bromus* density were noted in both trials at Asasa during the 1996 season (Table 11). In continuous wheat in the mechanized trial, burning reduced *Bromus* density dramatically compared to the other stubble management regimes. In wheat immediately following faba bean, mean *Bromus* density was lower than in continuous wheat, but the weed density was marginally higher where faba bean stubble had been removed in contrast to stubble burned or retained. Also, in the same trial, tillage method had no effect on *Bromus* density in wheat following faba bean; for continuous wheat, however, minimum tillage resulted in a significantly increased density of *Bromus*. In the ox-plow trial, continuous wheat with stubble removed exhibited a higher density of *Bromus* seedlings than the other three stubble management by cropping sequence combinations.

Table 10. Effects of treatments on *Bromus pectinatus* density[a] at maturity of bread wheat in 1994.

Treatments	Bekoji Mechanized	Bekoji Ox-plow	Asasa Mechanized	Asasa Ox-plow	Gonde
Straw management					
Burning	4.795 B	7.949 B	2.186	6.978 B	–
Removal	6.363 A	8.581 A	4.793	12.186 A	–
Retention	6.785 A	–	5.046	–	–
$LSD_{(a)}$ (5%)	1.33	0.619	NS	4.583	–
Tillage					
Conventional	5.224 B	6.198 B	3.114 B	9.000	4.125
Minimum	6.378 A	9.877 A	4.903 A	10.159	5.144
Cropping sequence					
Faba bean in 1992	5.449	7.838 AB	3.698	7.641 B	2.659 B
Rapeseed in 1992	5.532	7.356 B	3.496	10.017 A	4.996 AB
Barley in 1992	6.431	8.606 A	4.102	10.433 A	4.673 AB
Wheat (continuous)	6.512	8.351 AB	4.738	10.237 A	6.210 A
$LSD_{(b)}$ (5%)	NS	1.212	NS	1.803	2.37
Mean (detransformed)	35.3	64.1	15.6	91.3	21.0
C.V.(%)	28.8	12.7	64.9	22.3	40.8

[a] Densities transformed by $[X + 0.5]^{½}$.

*, *** significant at 5 and 0.01% levels, respectively.

Values followed by the same letter are not significantly different within the same treatment factor within columns.

Source: (20).

Table 11. Effects of interaction of cropping sequence with straw management and tillage on *Bromus pectinatus* seedling density[a] at Asasa in 1996.

	Cropping sequence	
	Faba bean	Wheat
Mechanized trial		
Straw management:		
Burn	1.047 D	1.670 CD
Remove	2.807 BC	3.768 AB
Retain	1.955 CD	4.906 A
Tillage:		
Conventional	1.669 B	2.012 B
Minimum	2.203 B	4.884 A
Ox-plow trial		
Straw management:		
Burn	1.580 C	1.981 BC
Remove	2.781 B	4.492 A

Interaction means followed by the same letter are not significantly different from each other (within the same interaction grouping) at the 10% level of the LSD test (except for the C x T interaction means which are separated at the 5% level of the LSD test).
[a] Transformed by SQRT (weed count/m^2 + 0.5).
Source: (5).

Thus, the density of *Bromus pectinatus* could be markedly reduced by occasional burning of crop stubble, by conventional tillage, and by adopting rotations with dicot crops. Since no herbicide is currently available to effectively control this weed, care should be taken not to induce a population shift towards grass weed species that cannot be easily reversed.

The future of IWM in Ethiopian wheat production

One of the challenges for IWM is promoting it as a viable component of cropping systems to farmers, extension personnel, government policy makers, and the public. If IWM is to be successfully adopted in Ethiopia during the coming decades, it must be as part of a broader systems approach that embraces environmental, economic, and social concerns that have not traditionally been a part of agricultural research but to which agriculture has relevance. The task of implementing IWM is daunting; nonetheless, progress has been made and IWM is beginning to move from the conceptual to the applied phase.

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Incidence and distribution of *Striga* on maize in Ethiopia

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Abstract

An extensive survey was undertaken during the 1997 crop season to determine the importance, incidence and distribution of Striga species on maize in some maize growing districts of Ethiopia. *Striga hermonthica* and *Striga asiatica* have been recorded in maize fields with the former being widespread and the latter having only localized importance. The overall Striga incidence (percent field samples in which Striga was present) in 310 maize field samples from districts with Striga was found to be 41%. The highest and the lowest Striga incidences recorded were 95% and 1.0% in Pawe and Dera districts, respectively. Fifty-six percent of the districts with Striga have incidences of 50% and above. Based on prevailing Striga damage symptoms on maize, yield losses of 40-50% were estimated in moderate to heavy infestations. Striga is a major biotic stress limiting maize production in the north, north-west, north-central and pocket areas in the southern and eastern parts of the country.

Introduction

Maize, an important cereal crop in Ethiopia, is cultivated on an area of about 1.1 million ha (1). The relatively high yield obtained per hectare and the favorable growing conditions have led to a trend of increasing maize production in the country. However, maize production is constrained by several important problems among which Striga can be included.

Three Striga species have been reported as capable of attacking maize in Ethiopia. The most widespread is *S. hermonthica* occurring in the northern, western, central and eastern parts of the country (2). The second, *S. asiatica*, was first reported as a problem on maize in a small area of Hararghe region in Habro district (5). The third is *S. aspera* reported on maize and wild grasses on two state farms in upper Birr and Finchaa (4).

Although the occurrence of Striga on maize has been reported, little attention was given to the problem in the country. The reason for the lack of appreciation of the severity of the problem might have been the absence of information about the extent and distribution of Striga infestation on maize. A survey to assess the magnitude and distribution of Striga on maize can provide a baseline data set to help prioritize the problem and judge its economic importance more effectively.

Unlike the case of maize, where some controversy still exists as to the importance of the Striga problem, the importance and distribution of Striga on sorghum in Ethiopia is well documented. It was, therefore, important to resolve this issue through an extensive survey in the major maize growing areas of the country. Hence, this survey targeted specific locations where maize is affected by Striga to assess the magnitude of the problem.

Materials and Methods

Field survey

Regions and districts were selected on the basis of the area under maize cultivation and on previous reports of Striga infesting maize. Guided tours were also made together with the Ministry of Agriculture agents to important sites where maize is grown on a large scale. Field samples were taken from selected districts at regular intervals (5-10 km) along the main roadsides. Small roads were also used in order to cover as much area as possible. The road network was selected using an Ethiopian tourist guide map produced in 1995 and a maize distribution map produced by the Ministry of Agriculture in 1982: 10-15 maize fields were assessed for each district. The actual number of fields assessed was proportional to the area under maize in the respective districts. Fields were selected to be representative of typical maize growing conditions found in each district. The incidence of Striga was measured by counting Striga shoots on four random samples of 4 m^2 each. The longitude and latitude of each site was fixed using a GPS (one per district) to facilitate mapping of Striga distribution on maize in the country.

Estimates of the average Striga population density (number/m^2) and Striga incidence for each district were extrapolated from these field samples. The surveyed maize fields were grouped into density classes of 1-10/m^2 and 11-50/m^2 and the proportion of fields occurring in each class was determined. The overall assessment of Striga damage (based on symptoms) was made. Other data such as altitude and maize variety grown were also collected.

Questionnaire survey

To supplement the field survey and obtain information on areas that were inaccessible to the field survey, a questionnaire was used. Questionnaires were distributed to crop protection team leaders of regions, zones and districts to determine the occurrence and status of Striga on maize in their respective administrative territories. The questionnaires distributed were detailed to obtain the respondents' opinion on the following main points:

- Importance and trend of the importance of maize
- Presence of Striga on maize
- Importance of Striga on maize
- Spread of Striga on maize
- Trend of Striga incidence on maize
- Abandoned maize production fields due to Striga
- How long Striga has been a problem on maize

Results and Discussion

The survey covered 55 districts in four regions in the north, north-west, east and southern parts of the country laying between 08^0-14^0N latitude and 36^0-42^0E longitude. *Striga hermonthica* is widespread and was recorded as infesting maize in the north, north-central, north-west and east; *Striga asiatica* was recorded in the east and southern parts of the country. Mixed infestation by *Striga hermonthica* and *Striga asiatica* was observed in Habro and Fedis (Harerghe) districts while only *Striga asiatica* was recorded in Gidole, Konso and Kucha (southern Ethiopia) districts. Parker *et al.* (3) reported the occurrence of both species in Habro district.

Out of a total of 310 maize fields sampled in the districts listed in Table 1, 127 fields (41%) were found to be infested with Striga. Variation in the incidence and level of Striga infestation was found among field samples within a district and also among districts (Table 1). Most of the districts were found to have more than 50% of their maize fields affected with Striga (Table 1). Heavily infested maize fields were prevalent in the following districts: Tehule Dere, Guba Lafto, Dewa Cheffa, Arthuma Jille, Alamata and Pawe. Tarma Ber, Adi Daro, Libo Kemkem, Fogera, Fnote Selam and Dera districts have a high proportion of maize fields with a low to moderate Striga infestation. Moderate to heavily infested maize fields were dominant in Kewot, Yifat and Tumuga, Kobo, Habro, Medeb Aizana, Kucha, Lay Armachiho and Yilmana Densa districts. Some large-scale maize producing enterprises were also visited and assessed for the status of striga infestation. Quantitative estimates of Striga incidence in sorghum and maize growing enterprises of Ethiopia was reported 10 years ago (6). The current situation of *Striga* in those particular maize producing enterprises is summarized

Table 1. Infestation level, incidence and distribution of *Striga* spp. in maize fields in some districts of Ethiopia.

District	Zone	[1]Mean Striga/m²	[2]Striga incidence (%)	Proportion of fields within Striga density count intervals		Sample position surveyed (Lat./Long.)	Elevation
				1-10/m²	11-50/m²		
Kewot[H]	North Shewa	11	65	43	22	09°59'N, 39°53'E	1450 - 1550
Yifat & Tumuga[H]	"	2	70	63	7	–	1600 - 1800
Tarma Ber	"	3	50	45	5	09°03'N, 38°42'E	1550 - 2600
Tehule Dere[H]	South Wollo	4	63	31	32	11°18'N, 39°27'E	1800 - 2500
Kobo[H]	North Wollo	8	55	29	26	12°04'N, 39°37'E	1550 - 1750
Guba Lafto[H]	"	5	56	15	41	11°53'N, 39°58'E	2000 - 2275
Dewa Cheffa[H]	Kemisie	13	63	33	30	10°38'N, 39°59'E	1550 - 1600
Arthuma Jille[H]	"	17	55	15	40	10°07'N, 39°58'E	1350 - 1600
Alamata[H]	South Tigray	26	45	13	32	12°24'N, 39°33'E	1550 - 1800
Korem[HH]	"	1	10	10	–	12°34'N, 39°31'E	2400 - 2575
Adi Daro[H]	West Tigray	1	22	22	–	14°19'N, 38°10'E	1800 - 2000
Medeb Aizana[H]	Central Tigray	9	78	34	44	14°05'N, 38°20'E	2000 - 2300
Lay Armachiho[H]	North Gondar	6	50	45	5	–	1550
Tach Armachiho[H]	"	12	65	65	–	–	1350 - 1550
Libo Kemkem[H]	South Gondar	0.05	20	20	–	12°03'N, 37°44'E	1750
Fogera[H]	"	0.3	5	5	-	–	1750 - 2050
Dera[H]	"	0.13	1.0	1.0	–	11°44'N, 37°30'E	1900
Yilmana Densa[H]	West Gojjam	13	29	19	10	10°38'N, 37°09'E	1600 - 1900
Fnote Selam[HH]	"	4	10	10	–	–	1550 - 2100

Table 1. Cont'd

Pawe[HH]	Metekel	46	95	37	58	11°19'N, 36°24'E	1200 - 1350
Konso	Special District	6	30	25	5	--	1450 - 1600
Gidole[H]	Special District	29	62	50	12	--	1300 - 2250
Kucha[HH]	North Omo	13	25	15	10	--	1400 - 1700
Fadis[H]	East Hareghe	43	31	12	19	09°14'N, 42°14'E	1500 - 1900
Habro[HH]	West Hareghe	14	28	3	25	08°42'N, 40°23'E	1750 - 1775

HH : maize covers >40% of area under cereals; H : maize covers 10-40% of area under cereals.

[1]Average of 40-60 observations from 10-15 field samples.

[2]Percent field samples in which Striga was present.

in Table 2. Scattered (in some fields extensively) patches of severe crop damage were observed in lower Birr, upper Birr and Cheffa state farms.

Results obtained from the questionnaire survey are summarized in Table 3. These results indicated an increasing trend in maize production, moderate to widespread occurrence of Striga on maize, and serious yield losses due to Striga in some districts in north and eastern Ethiopia.

The figures given for mean Striga estimates and percent Striga incidence in Tables 1 and 3 should be interpreted with caution (not to down play the level and extent of Striga) as they are taken from fields where hand pulling of Striga has been undertaken at least once and in most cases more than twice. It should also be noted that this survey was not exhaustive enough to give a country wide picture of Striga distribution and incidence in maize fields.

In infested fields where sorghum and maize are inter-cropped, it was clearly observed that maize suffers more injury than sorghum at a similar level of exposure to Striga infestation, indicating greater sensitivity of maize to Striga stress. In spite of this fact, the importance of Striga in maize did not attract research attention because of the reason that one can rarely see a dense stand of Striga flowering in maize fields (as is usually seen in sorghum fields) as maize would either die before Striga emerges, or could support relatively few Striga plants per stand and has a relatively short growing period as compared to sorghum.

Symptoms of Striga damage on maize were reduced stem diameter, reduced cob formation, moderate to severe leaf scorching, severe stunting and premature death. Based on prevailing Striga damage symptoms on maize, yield losses of 40-50% were estimated in moderate to heavy infestations. Extreme cases of total crop failure were also observed in Dewa Cheffa, Arthuma Jille, Medeb Aizana, Yilmana Densa, Habro, Fedis and Pawe. For example, in Pawe, maize yield was reduced from 50 q/ha to 10 q/ha due to Striga forcing farmers to abandon maize and shift to sorghum and other non-host crops (Teshale Asefa, personal com.).

Results of this survey confirmed that Striga is a major biotic factor limiting the expansion and intensification of maize production in the north and north-west parts of the country. There is also a real danger for the southern and eastern parts of the country to be invaded by Striga as there are already pocket areas/districts where severe infestation of Striga has been recorded (Table 1). Therefore, urgent containment measures should be targeted to key locations such as Kucha, Konso and Gidole districts to prevent the further spread of *Striga asiatica* to the most important maize belt of the country in the south, Fnote Selam district in the north-west to stop the alarming spread of *Striga hermonthica* to the maize belt of Wellega in the west, and Habro, Darolebu and Fedis districts in the east to prevent the spread to the rest of the maize and sorghum belts in Harerghe region.

Table 2. Results of Striga assessment in some maize growing enterprises in north and northwestern Ethiopia.

Enterprise	Zone	District	Area (ha)	Mean Striga/m^2	Striga incidence (%)	Sample position	Elevation (m)
Robi Prison Admin. Farm	North Shewa	Kewot	200	2	20	09°59'N, 039°53'E	1450
Cheffa State Farm	Kemisie	Dewa Cheffa	2700	21	10	10°49'N, 39°53'E	1600
Upper Birr State Farm	West Gojam	Fnote Selam	6000	3	5	10°38'N, 37°10'E	1900
Lower Birr State Farm	West Gojam	Fnote Selam	4000	24	70	10°29'N, 37°07'E	1550

Table 3. Results of the questionnaire survey on the occurrence and status of Striga on maize in some districts of Ethiopia.

		Maize production status		Striga status on maize			
			Trend in				Elevation
District	Zone	Importance	importance	Presence	Importance[1]	Spread[2]	(m)
Dita Deramallo	North omo	Dominant	Increasing	Not Present	–	–	–
Kobo	North Wello	Proportional	Increasing	Present	Serious	Widespread	1500
All districts	Sidama	Dominant	Increasing	Not present	–	–	–
Habru	North Wello	Homestead	No change	Present	Not serious	Localised	1560
Tehule Dere	South Wello	Proportional	Increasing	Present	serious	Moderately spread	1900
Ambasel	South Wello	Proportional	Increasing	Present	Serious	Moderately spread	1650
Desie Zuria	South Wello	Proportional	Increasing	Present	Not serious	Localised	1600-2550
Woldeya	South Wello	Homestead	No change	Present	Serious	Widespread	2000
Babile	East Harerghe	Homestead	No change	Present	Not serious	Localised	1450-2100
Chilga	North Gonder	Homestead	Increasing	Present	Not serious	Localised	900-2250
Gonder Zuria	North Gonder	Homestead	Increasing	Present	Not serious	Localised	1920
Belessa	North Gonder	Homestead	No change	Present	Serious	Moderately spread	1900
Meseia	West Harerghe	Proportional	Increasing	Present	Not serious	Localised	1440-1500
Darolabu	West Harerghe	Dominant	Increasing	Present	Very serious	Moderately spread	–
Boke	West Harerghe	Dominant	Decreasing	Present	Serious	Widespread	1450-1950
Habro	West Hararghe	Dominant	Increasing	Present	Very serious	Localised	1600-2400
Quni	West Harerghe	Dominant	Increasing	Present	Not serious	Moderately spread	1600-2000
Guba koricha	West Harerghe	Dominant	No change	Present	Very serious	Moderately spread	1500-2400
Adi Nebreid	West Tigray	Proportional	Increasing	Present	Serious	Widespread	1500-2100
Adawa Zuria	Central Tigray	Homestead	Decreasing	Present	Serious	Widespread	1500-1900
Kuiha Mekele	Central Tigray	Homestead	No change	Present	Serious	Widespread	$\geq$ 2100

[1] Serious = moderate yield loss; Not serious = Present but at low level; Very Serious = Heavy yield loss.

[2] Localized = 1-10 farms out of 200; Moderately spread = 11-50 farms out of 200; Widespread = > 50 farms out of 200.

Conclusion

Striga is a major biotic stress limiting the expansion and intensification of maize in the north, north-west and pocket areas in east and southern Ethiopia. Discussions with farmers revealed that maize is preferred to other crops due to its better yield per unit area. However, the problem of Striga coupled with the inherent sensitivity of maize to Striga, has forced farmers to abandon maize production or limit its culture to homesteads where better care could be given through manuring and other practices. Apart from hand pulling, there is no recommended control practice available to farmers to reduce the impact of Striga on maize. As a result, substantial maize yield loss is incurred every year. The unchecked rapid spread of Striga could threaten maize production in light of the inherent sensitivity of maize to this parasite. Thus, in Ethiopia sustainable maize production cannot be achieved without adequate attention to the containment and alleviation of Striga infestation.

Acknowledgments

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The distribution of *Striga in* Oromia region

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Abstract

Striga also known as *deeg'ssoo* in the region of Oromia is a wide spread problem. *Striga hermonthica* and *Striga asiatica* are the two most important species, affecting six major crops vis. barley, wheat, tef, finger millet, maize and sorghum in Eastern Oromia. Intensive crop production, free movement of agricultural commodities, population migration and poor regulatory measures have contributed to the build up of *Striga* infestation. Survey was conducted in ten weredas of Harerge Zone, in 1996 and 1997, aimed at building a reference collection of *Striga* species and host crop varieties, and providing a quantitative data for research priority setting in Oromia region. Two years survey results showed increased distribution of the weed with a mean of 2 shoots per m^2 on maize and sorghum. It is feared that the whole cereal growing areas of Oromia which, constitute 45% of the total land area devoted to those crops nationally, will soon be colonized by *Striga*, hindering Oromia's drive towards grain food self-sufficiency. Therefore, to minimize the spread and build up of infestation and associated crop losses all stake holders should collaborate through participatory approaches.

Introduction

Most species of *Striga* are root parasites of grain cereals and wild grasses in tropical and sub-tropical countries. The genus *Striga* includes about 60 species (Ba, 1984). Most African countries are severely infected by *Striga*. The weed is widely distributed in Ethiopia causing enormous crop losses. Parker (1988) reported that *Striga* is known to have occurred in Ethiopia for over 120 years but it has spread at an alarming rate, to colonize many parts of the country, recently. Except Sidamo, Jima, Illubabore, and parts of Welega other areas are prone to *Striga* infestation.

During 1984 - 1985, efforts have been made to establish where *Striga* severity occurred most in the state sorghum and maize farms. Early survey works have helped create public awareness of the problem in the state farms. In 1996-1997, survey was carried out in eastern and western Hararge aimed at establishing the distribution of *Striga* and building a reference collection of the different spp.

Sorghum, maize, finger millet, tef, wheat and barley being widely cultivated crops in the region suffer greatly from the infestation by *Striga*. There is a very serious concern that the whole of Oromia where, 45% (CSA, 1996/1997) of cereal production of the country is concentrated, will be invaded and colonized by *Striga*. This may hinder Oromia's drive towards grain food self-sufficiency in the near future. Therefore, to minimize further spread and subsequent crop losses, concerned institutions should colladborate and involve all stake holders for a joint effort against the noxious weed.

Materials and Methods

From 1994 to 1997 several training workshops were organized for 245 Subject Matter Specialists (SMS) working in twelve zones of Oromia. The participants were: 145 crop protectionists and 100 agronomists and extensionists. The workshops were held for one week each in Addis Ababa, Ziwaye, Ambo and Wolisso. The SMS, in turn, conducted similar training for field inspectors for one week in all the twelve zones. The training included instructions on survey methodologies, assessment and interpretation methods. Field visit was organized in Alemaya, Babile, Fedis, Boke, Habro and Kuni weredas to demonstrate how to conduct *Striga* surveys.

Senior Crop Protectionists and Weed Control Specialists of the Regional Bureau conducted regular visits to *Striga* prone areas of Oromiya to monitor activities and identify highly infested weredas that deserve increased attention for detailed *Striga* assessment. Among the different zones of Oromia, Hararge was the most severely infested area.

Striga occurrence, actual infested areas, host crops in hectarage, farm operations and *Striga* life cycle were assessed through the survey. In east Hararge, the survey was conducted in maize and sorghum growing areas of Alemaya, Babile, Bedeno, Fedis and Kurfa-Chele weredas. In west Hararge, Boke, Dardebu, Habro, Kuni and Messela weredas were covered. During field assessment crop protectionists, development agents, village leaders and farmers were involved.

Results and Discussion

Food grain cereals occupy most of the arable land in Oromia region. The actual cultivated land size for Meher and Belg is 45.10% of the total land devoted to cereal production in the country. Almost 10% of that is in east and west Hararge (CSA, 1996/1997). Training programs for 240 subject matter specialists from twelve zones of Oromia were given for four consecutive years on weeds, their assessment and control methods, with special emphasis to *Striga.*

The participants confirmed that *Striga* is the dominent and most troublesome weed in Hararge particularly on sorghum and maize and that infestation is further spreading to uninfested areas. Survey results also confirmed that nine zones of Oromia are serously infested (Table 1).

Taye and Yohanis (1998) noted that weed surveys made in the past, in Ethiopia, were general, largely based on observation and collections which do neither indicate the magnitude nor the economic importance of the weed.

East and west Hararge are characterized as highland semi-arid areas with scanty rainfall. Mixed farming is practiced in the area. Sorghum, maize tef, groundnut, sweet potato, safflower, chickpea, horse bean, field pea, *chat* and coffee are grown in rotation and as intercrops. Raising goats, cattle, sheep and camel are common.

In east Hararge, five weredas with 47 peasant associations (PAs) were found infested with *Striga hermonthica* and *Striga* asiatica. The total area that was infested in Fedis wereda alone was 4842 ha, which was 28.3% sorghum and 71.7% maize (Table 2).

In west Hararghe, a total area of 2363 ha of land, covered with tef, finger millet, sorghum and maize in 66 PAs of seven weredas, was found highly infested.

In east Hararge, the average infestation level of *Striga* on maize and sorghum was 23 and 18 shoots per m^2, respectively. In west Hararge, the mean *Striga* shoot count was 1, 2, 5, 8, 9, 18 on the six major crops-barley, wheat, tef, finger millet, maize and sorghum, respectively (Table 3).

Phenological studies carried out concurrently indicated that emergence of *Striga* occurs from June to August, tillering (July - September), flowering (August - October) and maturity (September-November) (Table 4).

Table 1. Distribution of *Striga* and affected crops in Oromia

Region	Species	Hosts crops
Arsi	*Striga hermonthica*	Maize and sorghum
Bale	*Striga hermonthica*	Maize and sorghum
Eastern Hararghe	*S. hermonthica*	Maize and sorghum
	S. asiatica	Maize and sorghum
Western Hararghe	*S. hermonthica*	Maize, sorghum, tef & wheat
	S. asiatica	Barley and finger millet
	S. gesnerioides	*Tephrosia* spp.
Eastern Shewa	*S. latericia*	Sugarcane
Western Shewa	*S. hermonthica*	Maize and sorghum
North-western Shewa	*S. hermonthica*	Maize, sorghum and tef
North Welega	*Striga aspera*	Maize
Borena	*S. hermonthica*	Maize and sorghum

Table 2. Hectarge of *Striga* infested weredas and crops.

Region	Wereda	*Striga* infested PAs (No)	Maize (ha)	Sorghum (ha)	Finger Millet (ha)	Tef (ha)	Total (ha)
East Hararghe	Alemaya	19	-	-	-	-	-
	Babile	9	-	-	-	-	-
	Bedeno	2	-	-	-	-	-
	Fedis	11	3471	1371	-	-	4842
	Kurfa Chele	6	-	-	-	-	-
West Hararghe	Boke	12	105	154	1	-	260
	Daro Welebu	27	228	615	14	2	859
	Doba	1	-	20	-	-	20
	Habro	10	220	501	4	19	744
	Kuni	10	76	284	13	-	373
	Mesela	5	7	95	-	-	102
	Mieso	1	-	5	-	-	5
	Total	113	3045 (42.3%)	4107 (57%)	32 (4%)	21 (3%)	7205

Note:
- - data not available

Table 3. *Striga* infestation level in the major crop of the surveyed weredas

Region	Wereda	Infested PAs (No)	*Striga* count (no/m^2)					
			B	W	T	FM	M	S
East Hararge	Babile	9	-	-	-	-	-	4
	Bedeno	2	-	-	-	-	-	5
	Alemaya	16	-	-	-	-	8	8
	Kurfa Chele	4	-	-	-	-	-	42
	Fedis	20	-	-	-	-	38	31
Total		51						
West Hararge	Boke	9	-	2	5	-	3	5
	Habro	13	1	-	-	-	7	5
	Dardebu	12	-	-	-	-	7	14
	Kumi	9	-	-	-	8	17	19
	Mesela	4	-	-	-	-	-	45
Total		47						
Mean			1	2	5	8	13	18

Note:-

B - Barley
M - Maize
W - Wheat
S - Sorghum
T - Tef
FM - Finger millet

Table 4. Crop calendar and *Striga* life cycle in Harerghe

Activity	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Ploughing			MMMMMMMMMMM SSSSSSSSSSSSSSSSS			TTTTTTTTTT						
Discing				MMMMMMM SSSSSSSSSSS			TTTTTTTTTT					
Planting				MMMMMMM SSSSSSSSSS			TTTTTTTTTT					
Hand cultivation					MMMMM SSSSSSSSSSSS							
Weeding					MMMMM SSSSSSSSSSSSS				TTTTTTTT			
Thining for feed						MMMMM	SSSSSSSSSSSSSSSSSS					
Harvesting									MMMMMMMMMMTTTTT	SSSSSSSSSSSSSSS		
***Striga* life cycle**												
Germination					....							
Seedling stage							....					
Tillering									....			
Flowering stage											....	
Maturity												

Note:-
M - Maize S - Sorghum T - Tef FM - Finger millet
* - Growth stages of *Striga*

Farmers noted that *Striga hermonthica* was observed in the area from 1970 on wards. According to the farmers, agricultural commodities, domestic animals and people, migrating in search of jobs and cultivable land, are the major means of spread.

Ahmed (1988) reported that *Striga* seeds were brought to Habro (Harerghe) from Selale (Shewa) by people who came looking for work. *S.hermonthica* is suspected to have spread to new areas in northern Shewa and make a long jump into Hararge, where it was not previous known, through similar means.

Presently, unrstricted movement of implements, animals and farm produce is leading to the enormous build up of infestation in Oromia, forcing farmers to give up cereal production. If this trend continues cultivation of maize and sorghum may be abondoned alltogether eventually (Wondimu, 1986).

Conclusion and Recommendation

The survey results confirmed that *Striga* incidence and distribution is highly increasing in Oromia region from year to year and from locality to locality, widening its host range. Geberemedhin et. al. (1998) reported that *Striga* is expanding its host range into tef, barley, wheat and several wild grasses in Tigray. Similar crops were found to be susceptible to populations occuring in Oromia.

The influx of people from *Striga* area to non-*Striga* area and poor regulatory measures have created favorable environment for the dissemination of the weed in the region. Still there is high possibility for *Striga* to colonize more areas and cause greater crop losses. Therefore, to minimize and eventually arrest the devastating effect of *Striga* effective regulatory measures have to be implemented at all levels.

The host range of *Striga* is expanding to barley, wheat, tef and finger millet, and thus coordinated and intensive research effort is required through collaboration of regional, national and international institutions.

Eight high yielding and *Striga* resistant sorghum cultivars, developed by Purdue University (USA) for wide use in *Striga* endemic areas of Africa, are being tested in Ethiopia such efforts should be strengthened in the future.

Chemical control and other agronomic methods should be combined as an integrated approach and widely disseminated to farmers.

The build up of *Striga* population, economic losses and the impact of various interventions should be apraised regularly. To monitor the distribution and severity and evaluate adaptability of technologies field workers should be trained on a regular basis by collaborating institutions.

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Results of a weed survey in the major barley and wheat growing areas of the Bale highlands

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Abstract

Weed species identification, quantification and prioritization are very important steps to design effective weed control measures. A weed survey was conducted in the ganna (belg) and bona (meher) seasons of 1997 in the Bale highlands (Sinana, Gasera, Agarfa and Dinsho districts) to identify, quantify and prioritize the major weed species in barley and bread wheat fields. A total of 52 weed species were identified, but 7 species have not been identified yet. The most important families according to the number of weed species within the families were: Compositae (8), Poaceae (4), Labiate, Polygonaceae and Cruciferae (2 each). The most frequent and dominant weed species in fields of both crops were *Guizotia scabra, Galinsoga parviflora, Chenopodium* spp., *Galium spurium,* and *Amaranthus hybridus*. Weed species composition varied across locations and seasons. Under present conditions, broadleaf weed species were more important since grass weeds are controlled by frequent plowing, except under the Sinana condition where *Cyperus blysmoides* was the dominant weed species during the bona (meher) season.

Introduction

Weeds, plants that interfere with the objectives and requirements of man (4), cause great yield losses in cultivated crops, particularly in areas where continuous cereal monoculture is practiced. However, before estimating crop yield losses due to weeds and devising weed control strategies, the identification and quantification of weeds in any location is very important. Because the degree of yield losses due to a weed depends on the species' competitive ability, relative growth rate, height, time of emergence (i.e., relative to the crop), leaf area, vegetative mass and density (1, 2, 3).

Weed growth, population density and distribution vary from place to place depending upon soil and climatic factors, and farmers' management practices.

Saavedra et al. (3) found that soil and climatic conditions affect weed flora. Therefore, to design effective weed control measures, the identification, characterization and quantification of the weed species in a certain area are important steps in describing a crop production system. Since yield loss and weed flora are related, information on weed density, distribution and species composition may help to predict yield losses. Such information also helps in deciding whether it is economical to control a specific weed problem (2).

In Sinana-Dinsho, Gasera, and Agarfa highlands, where barley and bread wheat are the major crops produced in the two annual cropping seasons, weeds represent one of the major problems. Even though a general weed survey had been undertaken 6-7 years ago, quantitative data has not been available. Besides a weed species composition shift and population dynamics changes could be expected as a result of farm management since the initial survey period. Accordingly, a weed survey for the Gasera, Dinsho, and Agarfa highlands was considered very essential. This survey was conducted to identify, quantify and prioritize the major weeds in the wheat and barley growing areas of the Bale highlands and to collect and preserve weed specimens in the Sinana Research Center herbarium.

Materials and Methods

The weed survey was conducted in the Sinana, Gasera and Agarfa districts during the two annual cropping seasons: ganna (belg) and bona (meher). The survey was conducted in Dinsho district only in the bona (meher) season of 1997/98.

A quadrat with a 0.5 x 0.5 m (0.25 m^2) sampling area was used to sample weed species. Observation, identification and counting individual weed species was thoroughly undertaken. Five samples, including two samples from an on-farm trial area at every 7 km interval, and a total of 25 samples were collected from each district depending on site conditions and the species area curve.

Specimens of weed species that were not identified during the assessment were collected, dried, mounted and maintained for identification. From the species composition and quantitative data the following statistics were calculated:

1. **Frequency (constancy):** $F = 100 * X/n$, where F = frequency, X = number of occurrences of a weed species, n = sample number.
2. **Abundance:** $A = \Sigma w/n$, where A = abundance, Σw = number of individual weed species, and n = sample number.
3. **Dominance:** $D = A * 100/\Sigma A$, where D = dominance, ΣA = abundance of all species

   Similarity index (community index): $SI = 100 * \Sigma[(Epg)/(EPg+EPa+EPb)]$

SI = Similarity index,
Epg = Number of species found in both location,
Epa = Number of species found only in location I,
Epb = Number of species found only in location II.

Weed species characteristics, average frequency and dominance over locations and seasons were analyzed (Table 1) for both belg and meher seasons (Tables 2 and 3).

Results and Discussion

A total of 52 weed species were identified. The most important families according to the number of represented species were Compositae (8 species), Poaceae (4 species), Labiate, Polygonaceae and Cruciferae (2 species each).

The frequency of the occurrence of individual weed species ranged from 3.01% up to 96.43% while the infestation level ranged from 0.09% up to 14.9%. *Guizotia scabra* was found to be the most frequent and dominant weed species. Weed species having frequency and dominance levels below 5.0% and 0.05%, respectively, were not included in the data presented because they occurred rarely and at low density.

There was a positive and significant relationship among weed species frequency, abundance and dominance ($P<0.01$), but some weed species that showed a high infestation level in certain locations were absent from other locations. For example, *Cyperus blysmoides* was the dominant weed species in Sinana district; however, it was less frequent than *G. scabra*. There was variation in weed composition between the two seasons and across locations. The similarity index of seasons was 54.8%. Taye et al. (5) indicated that if the similarity index among locations or seasons is less than 60%, the weed composition of locations or seasons should be considered as different. For example, *Cyperus blysmoides* was dominant in only Sinana during the bona (meher) season.

Only weed species which had frequency and infestation levels greater than 30% and 5%, respectively, were considered as major weeds because they constituted 50 to 90% of the total weeds infesting the cereal fields.

Table 1. Weed composition, frequency, and dominance in barley and wheat fields of three districts of Bale highlands (Sinana, Agarfa and Gasera) in the ganna (belg) and bona (meher) seasons of 1997.

Botanical name	Family	Characteristics	Frequency	Dominance
Guizotia scabra	Compositae	a	96.43	14.9
Galinsoga parviflora	Compositae	a	49.68	11.82
Chenopodium spp.	Chenopodiaceae	a	69.19	8.29
Amaranthus hybridus	Amaranthaceae	a	57.14	6.83
Cyperus blysmoides	Cyperaceae	a	12.13	6.61
Galium spurium	Rubiaceae	a	59.66	5.13
Plantago lanceolata	Plantagoceae	a/p	28.3	4.64
Scorpirus muricatus	Labiate/Lamiaceae	a	31.76	4.02
Flaveria trinervia	Compositae	a	8.70	3.67
Anagalis arvensis	Primulaceae	a	41.19	3.39
Phalaris paradoxa	Poacae	p	8.15	3.11
Commelina benghalensis	Commelinaceae	a	27.21	2.70
Digitaria scalarum	Poaceae	p	38.73	2.49
Erucastrum arabicum	Cruciferae	a	36	2.29

Table 1. Cont'd.

Leucas martinicensis	Labiate/Lamiaceae	a	13.8	1.89
Polygonum nepalense	Polygonaceae	a	24.57	1.71
Tagetes minuta	Compositae	a	12.9	1.58
Avena fatua	Poaceae	a	10.77	1.22
Solanum nigrum	Solanaceae	a/p	18.67	1.17
Raphanus raphanistrum	Cruciferae	a	18.29	1.00
Medicago sativa	Leguminosae	p	14.25	0.99
Corrigiola capensis	Caryophyllaceae	a	11.61	0.78
Chenopodium procerum	Chenopodiaceae	a	10.8	0.36
Fallopia convolvulus	Polygonaceae	a	3.01	0.21
Bidens pilosa	Compositae	a	8.25	0.14
Lolium temulentum	Poaceae	a	5.1	0.10

a = annual; p = perennial.

Table 2. Weed composition, frequency, and dominance in barley and wheat fields of three districts of Bale highlands (Sinana, Agarfa and Gasera) in the ganna (belg) season of 1997.

Botanical name	Family	Characteristics	Frequency	Dominance
Guizotia scabra	Compositae	a	96.05	15.4
Galinsoga parviflora	Compositae	a	66.04	15.39
Plantago lanceolata	Plantagoceae	a/p	45.83	9.31
Phalaris paradoxa	Poacae	p	15.05	7.88
Flaveria trinervia	Compositae	a	23.00	7.66
Amaranthus hybridus	Amaranthaceae	a	67.06	6.77
Tagetes minuta	Compositae	a	29.77	3.74
Bidens pilosa	Compositae	a	18.61	3.44
Digitaria scalarum	Poaceae	p	54.51	3.26
Anagalis arvensis	Primulaceae	a	57.53	2.78
Galium spurium	Rubiaceae	a	48.90	2.76
Commelina benghalensis	Commelinaceae	a	31.25	2.69
Chenopodium spp.	Chenopodiceae	a	51.27	2.48
Solanum nigrum	Solanaceae	a/p	39.78	2.27

Table 2. Cont'd.

Leucas martinicensis	Labiate/Lamiaceae	a	18.50	1.44
Corrigiola capensis	Caryophyllaceae	a	21.15	1.23
Scorpirus muricatus	Labiate/Lamiaceae	a	15.26	1.11
Polygonum nepalense	Polygonaceae	a	10.00	0.71
Chenopodium procerum	Chenopodiaceae	a	21.6	0.54
Bidens pachylome	Compositae	a	4.55	0.41
Fallopia convolvulus	Polygonaceae	a	6.15	0.32
Erucastrum arabicum	Cruciferae	a	12.25	0.29
Medicago sativa	Leguminosae	p	8.90	0.25
Euphorbia spp.	Euphorbiaceae	a/p	9.30	0.22
Raphanus raphanistrum	Cruciferae	a	6.4	0.17
Cynodon dactylon	Poaceae	p	4.35	0.09

a = annual; p = perennial.

Table 3. Weed composition, frequency, and dominance in barley and wheat fields of three districts of Bale highlands (Sinana, Agarfa, Dinsho and Gasera) in the bona (meher) season of 1997.

Botanical name	Family	Characteristics	Frequency	Dominance
Guizotia scabra	Compositae	a	96.63	12.89
Cyperus blysmoides	Cyperaceae	p/a	20.40	12.53
Chenopodium spp.	Chenopodiaceae	a	78.9	11.98
Amaranthus hybridus	Amaranthaceae	a	46.13	10.82
Galium spurium	Rubiaceae	a	64.85	8.73
Scorpirus muricatus	Labiate/Lamiaceae	a	43.04	6.36
Galinsoga parviflora	Compositae	a	38.34	5.57
Erucastrum arabicum	Cruciferae	a	50.20	4.98
Anagalis arvensis	Primulaceae	a	26.69	2.76
Polygonium nepalense	Polygonaceae	a	31.89	2.7
Raphanus raphanistrum	Cruciferae	a	20.26	2.28
Plantago lanceolata	Plantagoceae	a/p	18.76	2.04
Medicago sativa	Leguminosae	p	19.60	1.98
Comalina benghalensis	Commelinaceae	a	20.95	1.83
Digitaria scalarum	Poaceae	p	21.67	1.53
Lolium temulentum	Poaceae	a	6.30	0.16
Cynodon dactylon	Poaceae	p	5	0.14

a = annual; p = perennial.

Ganna (belg)

The frequency and dominance of individual weed species ranged from 2.0% up to 96.05% 0.02% up to 15.40%, respectively. *G. scabra* was the most frequent, but both *G. scabra* and *Galinsoga parviflora* were dominant in weed infested fields. These two weed species contributed up to 31% of the infestation of weeds in the cereal fields.

Sinana

All major weeds, except *Phalaris paradoxa*, were broadleaf species, comprising up to 60% of the weeds infesting the cereal fields. *G. scabra* was the most frequent and dominant weed species contributing 20% of the weed infestation.

Gasera

Major weed species represented 50% of the total weed flora. *G. scabra* was found frequently, but *G. parviflora* dominantly infested the fields. These two major weeds represented 40% of the weed infestation.

Agarfa

Chenopodium spp., *Anagalis arvensis*, *Scorpirus muricatus* and *Plantago lanceolata* were frequently found in the cereal fields. However, they represented only 16.6% of the total weeds infesting the fields. *G. scabra* was the most frequent weed species. *Amaranthus hybridus* exhibited twice the infestation level of the other major weed species.

Bona (meher)

The frequency and dominance level of individual weed species ranged from 2.8% up to 75% and 0.1% up to 16.2%, respectively. *G. scabra* was the most frequent while while *Cyperus blysmoides* was as dominant as *G. scabra.*

Sinana

Major weed species represented about 62% of the infestation level. *G. scabra* and *Erucastrum arabicum* were the most common weed species. Only *Cyperus blysmoides*, which represented 35% of the weeds infesting the fields, was dominant.

Gasera

While *G. scabra* was frequently distributed in this district, *G. parviflora*, which represented one-fifth of all weeds in the fields, was the dominant weed species. The three weed species (*G. scabra*, *G. parviflora* and *G. spurium*) represented about one-half of the total weeds in the cereal fields.

Agarfa

G. scabra, which had an infestation level of about 23%, was the most frequent and dominant weed species. The three major broadleaf weed species (*G. scabra*, *Chenopodium* spp., and *G. spurium*) represented up to 60% of the total weed infestation.

Dinsho

G. scabra frequently infested fields. It also dominantly infested all fields. This weed species represented more than a quarter of the weeds infesting fields. In these fields, even though many weed species were found, only a few weed species were considered as major weeds.

Farmers' practices to control weeds

Most farmers in the surveyed areas do not commonly weed their barley and wheat fields. They entirely depend on cultural weed control practices such as frequent tillage (i.e., four to six times), starting two to four months before planting, and the use of seed rates greater than 200 kg/ha. Frequent tillage helped to reduce perennial grass weeds and to decrease the broadleaf weed seed bank. Farmers gave more attention to larger weed species as these weeds create problems during harvesting. Finally, farmers on approximately 5% of the surveyed fields applied 2,4-D to control broadleaf weeds even though the rate and time of application were not in accordance with the recommendations. Farmers use 50-100 kg DAP/ha fertilizer for barley and bread wheat production.

Conclusion

Most of the major weed species were broadleaf species. Any weed control strategy should focus on these major weeds. It is also important to identify the economic threshold for major weed species.

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Mesquite (*Prosopis juliflora*) in Ethiopia

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Abstract

Prosopis juliflora, known as mesquite in North and Central America and as "*Weyanne*" in Ethiopia, is a member of the plant family Leguminoseae. Although animals may browse this plant, its unmanageable and thorny characteristics render it a difficult weed. *Mesquite* is a very problematic weed which is spreading at an alarming rate in eastern Ethiopia since the mid-1980s with the establishment of the Middle Awash Agricultural Development. At present, this weed is common in the Middle and Upper Awash Valley and in the eastern parts of Hararge. It has become a serious problem on large-scale farms and on grassland ranges. Ministry of State Farms staff have periodically taken action to remove the weed using human labor; this approach attained moderate control at a high cost. No fully effective and suitable control measures are available to date.

Introduction

Mesquite (*Prosopis juliflora)* is a native of North and Central America and has been spread by human and animal dispersal across regions and continents (15), and is now spreading at an alarming pace in Ethiopia. There is so far no information on how this weed was introduced into this country but it was first reported from the Middle Awash (16). At present, it occurs commonly in the Middle and Upper Awash Valley and eastern parts of Hararge and it has become a serious problem on the large-scale farms and grassland ranges. The carrying capacity of many rangelands has been seriously reduced owing to its aggressive nature, which makes it highly suppressive to other plants. It has invaded large-scale farms, grazing lands and riverbanks, and also serves as a host plant for insect pests on the cotton farms in the Awash Valley (16). It also has allelopathic effects, reducing radicle growth but not germination of sorghum, wheat, maize, safflower, and cowpeas (17, 24). The dissemination of its seeds with cattle dung has been an important factor in its spread (12). It grows well up to 1500 m in altitude and thrives in areas with light and sandy soils where the average annual rainfall is at least 250 mm. *Mesquite* is adapted to low rainfall and hence withstands drought for a prolonged period under desert temperatures (16). This paper reviews the literature on the biology and control of mesquite from research conducted abroad and in Ethiopia.

Distribution in Ethiopia

In Ethiopia, mesquite was first officially reported three years ago (16). At that time, the weed was abundant in parts of the Middle and Upper Awash and also occurred in Eastern Hararge on many ha of cultivated land. It grows up to 1500 m a.s.l., and thrives on poor or fertile highly saline and sandy soils and seasonally water-logged wasteland. Mesquite is adapted to low rainfall and hence withstands drought for a prolonged period under desert temperatures (16). Today, mesquite is rampant over a much wider range of ecologies than its original incidence, and has become a serious problem in the nomadic settlement areas of the Afar region. The carrying capacities of many ranges have been seriously reduced due to its tremendous increase (16). The flowering time of mesquite extends from March to August, but is concentrated principally from May to June. Its pods are relished by all livestock; unlike most other legumes, mesquite plants do not shed their seeds. Dissemination of the seeds in cattle dung is an important factor in the weed invasion as the seeds don't loose their viability in the animals stomach (12). They can also be transported by water over long distances without being physiologically affected. As a result, the spread of the plant to alluvial soils is increasing environmental concern, as it demands a high cost to clear it from agricultural and grazing fields, and canal banks and roadsides (6, 16).

Biology

Mesquite is a perennial weed belonging to the family Leguminosae (15, 26). It is a spiny deciduous shrub or a small tree 30-50 feet in height, with a trunk of 1-4 feet in diameter, and is usually armed with yellowish, stout, nearly straight spines arising in pairs, 0.25-3.0 inches long. The leaves are 3-8 inches long; the first divide into 1-2 pairs of primary divisions. Each of these is again divided into about 10-28 pairs of finely hairy or hairless secondary leaflets, 0.125-0.75 inches long. The small fragrant greenish-yellow flowers are crowded on stalked spikes of 2-5 inches in length. The flat tan-colored leatherish pods are finely hairy or hairless, 3-8 inches long and each may contain from 2-20 seeds with a sweetish pulp. The rough bark separates into dark strips, and the wood is hard, reddish brown, with yellow sapwood (15).

Control measures

It should be noted that integrating control methods to suit specific situations is desirable and recommended. The following discussion covers each type of control measure; any combination can be included in an integrated control program.

Preventive control

Quarantine is particularly important in minimizing the movement of weeds across national boundaries. Peasant farmers should protect crops in homestead farms from ruminants by sprinkling the crops with a mixture of water and sheep or goat droppings, or a water slurry that keeps grazing animals away from crops.

Manual control

1. Hand weeding: probably the oldest method of weed control and consists of hand pulling, hand slashing and hoeing, and mowing of weeds. It is, however, laborious, unattractive and full of drudgery. It is also expensive when cheap labor is in short supply, and is ineffective against perennial weeds and when weeds can't be pulled completely out of the soil.
2. Hand hoeing: by far the most widely used.
3. Hand slashing: another manual weed control method used mainly in rights of way, on crop areas, and in plantation crops.

Mechanical control

This includes all weed control practices where a mechanical device is used for weed control with animals or fossil fuel as the source of energy. Generally, removal of mesquite by hand or machine is a relatively expensive operation. Burning can be used where the area of infestation is not extensive, where there is relatively easy site access, and where labor is cheap. This method has been used by state farms in the past, although infestations were not eliminated.

Chemical control

The choice of herbicide depends upon the magnitude of infestation, the location, the presence of susceptible crops, hazards to the environment and non-target vegetation. Many reports have indicated chemical control is a promising method controlling mesquite. Picloram and chlopyralid at 0.2 and 0.5 kg/ha have been highly and consistently effective when applied to *P. juliflora* var. *glandulosa* (1, 5, 19, 20). When 0.6 kg a.i. 2,4,5-T/ha was applied to range land in New Mexico, 7-64% of *Prosopis juliflora* was killed (11). Aerial application of the ester formulation of triclopyr at 0.3-1.1 kg a.i./ha at a number of sites in Texas, USA, gave best control of *P. juliflora* var. *glandulosa* (13).

Picloram and 3,6-dichloropicolinic acid were also effective against honey mesquite (1, 2, 3, 4, 14). Effective control was obtained with an overhead spray on bushes of AMS (ammonium sulphamate) at 125 kg/ha mixed with 2,4,5-

T+2,4-D (3.75 kg/ha); of 20 bushes sprayed, only 2 to 3 showed new shoots after three months (25). Likewise, application of AMS paste (3 and 4 kg/5 l water) with a hand brush on the girdled and stumped portions of the trees was very effective in killing 80 to 90% (21, 25). In terms of root-killing, Tordon 225 at a rate of 0.125 1b is adequate, while 2,4,5-T at 0.25 lb or 2,4-D at1 lb/acre were found economically as well biologically efficient (1, 11, 29). Low volume aerial application of 2,4,5-T ester at 0.5 1b/acre and picloram + 2,4,5-T each at 0.25 lb/acre gave excellent top kill of honey mesquite (2, 7, 10, 23, 27, 29). Mixtures of picloram + dicamba at 0.56 kg or 1.12 kg/ha of each compound applied in July effectively defoliated honey mesquite and killed 33% of plants (22). EL-103 (tebuthiuson) at 2, 4 and 8 lb/acre caused defoliation and gradual death of the mesquite (30).

Biological control

Cutworms caused severe defoliation of honey mesquite on heavy clay and bottom land range sites in the rolling plains of Texas following a late spring freeze and a drought in 1971 (31). In some areas, cutworms reduced mesquite foliage by 95%. In Haryana, India, bark-boring larvae of *Indarbella* spp. were found since 1971 for the first time on *Prosopis juliflora* (34). Observation in 1976-8 at the Santa Rita experimental range near Tucson, Arizona showed that large numbers of *Lepus calitornicus*, *L. alleni* and *Loportyx gambelli* were seen in undisturbed stands of *Prosopis juliflora* var. *velutina* (8). In the middle Awash (cotton growing) area Aphids and Jassids were also found on *Prosopis juliflora*. The leaf footed bug *Mozena obtusa* was observed feeding on immature mesquite pods at relatively high population densities in the rolling plains area of Texas during the summer of 1971 and reduced the dry weight of the pods, and dry weight and germination of the seeds (32).

A plan for Ethiopia

Integrated control has been found to be most effective, globally including biological control, chemical control, and mechanical control such as cutting and shading. The first task is to make a map of infested areas. The areas can then be typed and assigned a priority rating according to the weed importance and necessity for control. Then suitable control measures could be assigned to each of the identified area types. Study of ecology and habitat, given the fact that this information is crucial towards establishing a long-term control program, is proposed to be carried out with support from relevant institutions.

The biology and ecology of mesquite in the Middle and Upper Awash and eastern parts of Hararge should be studied to understand the source of infestation, and to map the area as well as categorize the environments where the weed is thriving.

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The following details should be included:

1. Identify and study any herbivores, diseases and insects that are naturally attacking mesquite in Ethiopia.
2. Study potential biological control agents that could be introduced into Ethiopia. Studies should include host preferences, rearing and release techniques, and adaptability.
3. Biological control involves complex interactions, but is feasible and less expensive to establish. Biological control, as used elsewhere, includes spraying of fungal diseases and introducing and encouraging insect pests which eat the weed. Strict quarantine procedures are required when introducing foreign species to minimize potential side effects. Thus, biological control, in this case, could be considered as a short-term solution. International organizations such as CABI can be contacted for assistance. It should also be noted that a series of control measures must be in effect for a long period to keep the weed under control as it appears that its habitat is very wide, making it difficult to eradicate it completely.

Use of Mesquite

Although a weed, the mesquite biomass once removed can be used for various purposes: it can be exploited for food, fodder, honey, fencing material, fuel and wood pulp. Also its spread to soils with high salinity and poor fertility has a positive impact in reclaiming wasteland (3, 6, 9, 16, 18, 28, 33).

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The relative tolerance of three bread wheat varieties to weed competition

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Abstract

The relative tolerance of three bread wheat varieties (Dashen, ET-13 and Enkoy) to weed competition was studied at the Adet Research Center on Nitosols during the 1989 and 1990 Eth. Ca. cropping seasons. The results indicated that out of the major weed species recorded on the experimental field, 70% were broadleaf weeds. At maturity, *Guizotia scabra* was found to be the dominant weed species with the highest number of plants ($120/m^2$) followed by *Polygonum nepalense* ($68/m^2$) and *Setaria pumila* ($66/m^2$). On average, next to the control, the highest weed density was recorded on plots weeded 30 days after planting. The lowest weed density was recorded on plots weeded 30 + 60 days after planting followed by weeding 20 + 45 days after planting. Grain yield differences were significant among varieties (P=0.02) and weeding (P=0.001). However, variety x weeding interaction was not significant. The highest mean grain yield (35 q/ha) was obtained on plots weeded 20 + 45 days after planting. Mean grain yield losses due to weed competition on the control plots were 42% for Dashen, 37% for ET-13 and 24% for Enkoy. Late weeding (60 days after planting) resulted in grain yield losses of 17, 34 and 9% for Dashen, ET-13 and Enkoy, respectively. Similarly the losses due to a single early weeding (30 days after planting) were 14% for Dashen, 12% for ET-13 and 7% for Enkoy.

Introduction

Since the mid 1980s, a number of improved bread wheat varieties have been introduced and distributed to farmers in almost all high potential areas of north-western Ethiopia. Among the varieties, ET-13, Enkoy and Dashen are the highest yielding and best adapted cultivars for the agro-climatic conditions of north-western Ethiopia (Fekadu Fufa, 1990, unpub.). Despite the genetic potential of the new varieties, the yields on farmers' fields are very low. Among the problems that limit productivity of these varieties are the lack of improved agronomic practices to accompany improved seed. Notable among these are timely and effective weeding.

The crop production system in north-western Ethiopia is cereal-dominated (i.e., growing traditional crops with varying cultural practices as in the case of tef to which highest priority as well as maximum inputs are given). Studies to determine the initial period of competition, optimum time of hand weeding, and yield losses due to weed competition on wheat indicated that the critical time of weed competition is three weeks after germination and yield loss due to weeds is about 36% (1). Another study on weed emergence patterns at Adet clearly showed that broadleaf weeds were dominant and germinate along with the crop on both Nitosol and Cambisol soil types (2). Wheat varieties differ in their tolerance of weed competition (3). Understanding the ability of varieties to tolerate weed competition would help farmers to budget their limited time for various farm operations. Therefore, this experiment was conducted to evaluate the relative tolerance ability of Dashen, ET-13 and Enkoy to weed competition.

Materials and Methods

The field experiment was conducted at the Adet Research Center on a Nitosol during the 1989 and 1990 main cropping seasons. For each variety, a seed rate of 150 kg/ha was broadcast and a fertilizer rate of 60/60 N/P_2O_5 kg/ha were used. The plot size used was 3.2 m x 5 m with a net plot size of 12 m^2. The trial was laid out in a split plot design consisting of three replications with varieties viz. Dashen, ET-13 and Enkoy as main plots and six levels of weeding (i.e., 0, 20 + 45, 30, 45, 30 + 60 and 60 days after planting) as sub plots. Weed counts were taken twice (i.e., at the time of weeding and at crop maturity) using a quadrat of 0.25 m^2 at two spots per plot.

Results and Discussion

The major weed species recorded on the experimental field were *Setaria pumila*, *Cyperus* spp., *Guizotia scabra*, *Trifolium* spp., *Spermacoce spharestigma*, *Polygonum nepalense*, *Commelina subulata*, *Caylusia abyssinica*, *Plantago lanceolata* and *Digitaria* spp. Seventy percent of the weeds were broadleaf species. At maturity, *Guizotia scabra* was the dominant weed with the highest number of plants (120/m^2) followed by *Polygonum nepalense* (68/m^2) and *Setaria pumila* (66/m^2). The two broadleaf weeds (*Polygonum nepalense* and *Guizotia scabra*) are the most noxious weeds of cereals in the region and have a regular emergence pattern from the onset of rain to the end of the rainy season (2).

Among the sub-plot treatments, average weed density was higher on the control, the highest being on Dashen plots followed by ET-13 and Enkoy plots. *Setaria pumila*, *Guizotia scabra* and *Polygonum nepalense* densities were higher on the control than other weed species. Next to the control, the highest weed density was recorded on plots weeded 30 days after planting. Plots weeded 30 + 60 days after planting had the lowest mean weed density followed by weeding at 20 + 45 days after planting (Table 1).

From the analysis of variance over years, (Table 2) grain yield differences were significant among varieties (*P*=0.02) and weeding (*P*=0.001). However, variety x weeding interaction was not significant. Mean yield was highest for Dashen followed by Enkoy. Average grain yield varied between 36 q/ha on plots weeded 20 + 45 days and 27 q/ha on the control (Table 3). The highest mean yields, 41 q/ha for Dashen and 34 q/ha for ET-13, were recorded on plots weeded 20 + 45 days after planting, whereas for Enkoy the highest yield (34 q/ha) was obtained on plots weeded 45 days after planting. In the case of ET-13 and Enkoy, the lowest yields next to the control were recorded on plots weeded 60 days after planting. For Dashen the lowest yield was recorded on plots weeded 30 days after planting.

Mean grain yield losses due to weed competition on the control were 42 percent for Dashen, 37 percent for ET-13 and 24 percent for Enkoy. Late weeding (60 days after planting) resulted in grain yield losses of 17, 34 and 9 percent for Dashen, ET-13 and Enkoy, respectively. The high loss on ET-13 relative to the other varieties could be due to its tall stature that makes it susceptible to physical damage during late weeding.

Similarly, the losses recorded on single and early weeded (30 days after planting) plots were 14 percent for Dashen, 12 percent for ET-13 and 7 percent for Enkoy. This high loss, particularly on Dashen, was probably due to its slow early growth reducing its ability to suppress emerging weeds. Early weeding, unless repeated, can result in the emergence of many more weeds. This is evidenced by the higher weed density on plots weeded 20 days after planting.

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Table 1. Mean weed density before weeding and at crop maturity (1989-1990).

Treatment	Dashen		ET-13		Enkoy	
	before weeding	at maturity	before weeding	at maturity	before weeding	at maturity
Control	--	207	--	199	--	193
20 + 45	199/215	38	144/210	42	172/214	44
30	326	87	247	86	254	81
45	376	60	311	77	296	69
60	368	69	327	62	301	48
30 + 60	360/208	33	392/196	53	299/216	34

Table 2. Analysis of variance for grain yield across years (1989-1990).

Source of variance	Grain yield
year	0.01
variety	0.02
year x variety	NS
weeding	0.001
year x weeding	0.006
variety x weeding	NS

Table 3. The effect of weeding time and frequency on the grain yield (q/ha) of three bread wheat varieties (1989-1990).

Treatment	Variety			Mean
	Dashen	ET-13	Enkoy	
Control	29	25	27	27
20 + 45	41	34	32	36
30	35	30	32	32
45	38	31	34	34
60	36	25	31	31
30 + 60	40	32	32	35
Mean	37	29	31	

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Results of a weed survey in the major field pea and faba bean growing areas of the Bale highlands

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Abstract

Weed species identification, quantification and prioritization are very important preliminary steps before designing effective weed control measures. Weed surveys were conducted in the ganna (belg) and bona (meher) seasons of 1997 in the Bale highlands (Sinana, Gasera, Agarfa and Dinsho districts) to identify, quantify and prioritize the major weed species in field pea and faba bean fields. A total of 43 weed species were identified. The most important families according to the number of weed species encountered were: Compositae (6), Poaceae (4), Labiate, Polygoniaceae, Chenopodiaceae and Cruciferae (2 each), and Rubiaceae (1). The most frequent and dominant weed species in fields of both crops were *Guizotia scabra, Galinsoga parviflora, Bromus pectinatus, Galium spurium,* and *Amaranthus hybridus*. Even though these weed species were major in fields of both crops and during both seasons, species composition varied across locations and seasons. Broadleaf weed species were more important in faba bean than in field pea fields. Grass weeds are, however, more prevalent in field pea fields due to less attention by farmers to land preparation for this crop. There were some patchy weed species, which occurred at high infestation levels but only in certain locations and seasons.

Introduction

Weeds, plants that interfere with the objectives and requirements of man (4), cause a great yield loss in cultivated crops. However, before estimating crop yield losses due to weeds, and devising a weed control strategy, the identification and quantification of weeds in any location is very important. The degree of yield loss due to weeds in any crop depends on the species' competitive ability, relative growth height, time of emergence (relative to the crop), leaf area, vegetative mass and density (1, 2, 3).

Weed growth, population density and distribution vary from place to place depending upon soil and climatic factors, and farmers' management practices. Saavedra et al. (3) found that soil and climatic conditions affect weed flora.

Therefore, in order to design effective weed control measures, the identification, characterization and quantification of the weed species in a certain area are important steps in describing a crop production system. Since yield loss and weed flora are related, information on weed density, distribution and species composition may help to predict yield loss. Such information also helps in deciding whether it is economical to control a specific weed problem (3). Accordingly, a weed survey was conducted in 1997 in the Bale highlands (Sinana, Gasera, Agarfa and Dinsho) to identify, quantify, and prioritize the major weeds in faba bean and field pea fields.

Materials and Methods

The weed survey was conducted in Sinana, Gasera and Agarfa districts during the ganna (Belg) season only in field pea fields; weeds were surveyed at Agarfa, Gasera and Dinsho in both field pea and faba bean, and Sinana only in field pea fields in the bona (meher) season of 1997/98. Those areas which did not produce field pea or faba bean in the respective seasons or districts were excluded from this paper.

A quadrat with an area of 0.5 m x 0.5 m (0.25 m^2) sampling area was used to sample the weed species. Observation, identification and counting of individual weed species was thoroughly undertaken. Three samples were taken at every 7 km interval, and a total of 15 samples were collected from each district depending on site conditions and the species area curve. Specimens of weed species that were not identified during the assessment were collected, dried, mounted and retained for subsequent identification. From the weed species composition and quantitative data, the following were calculated:

Frequency (constancy): $F = 100 * X/n$, where F = frequency, X = number of occurrences of a weed species, n = sample number.

Abundance: $A = \Sigma w/n$, where A = abundance, Σw = sum of observations of an individual weed species, and n = sample number.

Dominance: $D = A * 100/\Sigma A$, where D = dominance, ΣA = abundance of all weed species.

Similarity index (community index): $SI = 100*EPg/\Sigma (Epg + Epa + EPb)$, where

SI = Similarity index
Epg = Number of species found in both locations
Epa = Number of species found only in location I
Epb = Number of species found only in location II

Weed species characteristics such as frequency, abundance and dominance over locations for both 'gena' (belg) and 'bona' (meher) seasons were calculated (Tables 1 and 2). As there was no faba bean production in the genna season, only the survey results of field pea were presented.

Results and Discussion

A total of 43 weed species were identified. The most important weed species in fields of both crops were *Guizotia scabra, Galinsoga parviflora, Bromus pectinatus, Galium spurium,* and *Amaranthus hybridus*.

In the ganna (belg) season, the frequency and dominance of individual weed species ranged from 3.7 up to 87%, and 0.06 up to 13.9%, respectively, in field pea fields (Table 1). However, in the bona (meher) season, the frequency of individual weed species ranged from 5.6 to 75% and 11.1 to 88.9% for field pea and faba bean, respectively. The dominance level was 0.4 to 16.2 and 0.5 to 20.5 for field and faba bean, respectively. Weed species having frequency and dominance levels below 5.0 and 0.4%, respectively, were excluded because they occurred rarely and at low density.

The similarity index across locations, between two crops and seasons were less than 60% (Tables 3, 4 and 5), indicating the variation of weed species composition across locations, between seasons and crops. Taye et al. (5) indicated that if the similarity index among locations or between seasons is less than 60%, the weed composition of locations or seasons should be considered as different.

Even though the same major weed species were found in both faba bean and field pea fields, the infestation level of a specific weed species in one crop was different from the other. For instance, *Galinsoga parviflora* infested faba bean fields up to 21%, but it represented only 6% of the weeds in field pea. Because farmers plough their fields more frequently for faba bean than for field pea, grass weed infestation was prevalent in field pea fields (Table 2). On the contrary, higher broadleaf weed infestation was observed in faba bean than in field pea fields (Table 2).

Galinsoga parviflora, Amaranthus hybridus and *Chenopodium* spp. were major weed species in faba bean, but they were not as common in field pea fields. However, *Digitaria scalarum* and *Commelina benghalensis* were the major weeds observed in field pea (Table 1).

Table 1. Weed composition, frequency, and dominance in field pea fields of three districts of Bale highlands (Sinana, Agarfa and Gasera) in gannaa of 1997.

Botanical name	Family	Characteristics	Frequency (%) Field pea	Dominance (%) Field pea
Guizotia scabra	Compositae	a	87.0	11.60
Phalaris paradoxa	Poacae	a	12.4	0.70
Erucastrum arabicam	Crucifrae	a	16.2	0.40
Galinsoga parviflora	Compositae	a	70.5	13.90
Digitaria scalarum	Poaceae	p	64.6	7.60
Scorpiurus muricatus	Labiate/lamiaceae	a	14.1	0.80
Flaveria trinervia		a	25.5	6.50
Tagetes minuta	Compositae	a	21.5	1.50
Gallium spurium	Rubiaceae	a	79.1	5.20
Bidens pilosa	Compositae	a	31.9	6.30
Chenopodium spp.	Chenopodiaceae	a	32.3	1.10
Amaranthus hybridus	Amaranthaceae	a	46.9	5.50
Anagalis arvensis	Primulaceae	a	64.2	4.40
Plantago lanceolata	Plantigoceae	a/p	45.0	4.10
Leucas martinicensis	Labiate/lamiaceae	a	29.6	3.60
Corrigiola capensis	Ceryophyllaceae	a	19.2	1.60
Euphorbia spp.	Euphoribiacea	a/p	7.0	0.06
Fallopia convolvulus	Polygoneaceae	a	16.2	2.20
Polygonum nepalenses	Polygoneaceae	a	7.0	0.20
Commelina benghalensis	Commelinaceae	a	48.4	6.40
Lolium temulentum	Poaceae	a	13.8	0.60
Chenopodium procerum	Chenopodiaceae	a	25.5	1.20
Medicago sativa	Leguminosae	p	7.0	0.50
Cynodon dactylon	Poaceae	p	6.0	0.50

a = annual, p = perennial.

Table 2. Weed composition, frequency, and dominance in field pea and faba bean fields of four districts of Bale highlands (Sinana, Gasera, Aagarfa and Dinsho) in bonaa of 1997.

Botanical name	Family	Characteristics	Frequency (%)		Dominance (%)	
			Field pea	Faba bean	Field pea	Faba bean
Guizotia scabra	Compositae	a	75.0	81.5	10.1	11.3
Erucastrum arabicum	Cruciferae	a	44.4	-	5.1	-
Galinsoga parviflora	Compositeae	a	47.2	88.9	6.4	20.5
Digitaria scalarum	Poacae	p	44.4	22.1	2.3	0.8
Scorpiurus muricatus	Labiate/lamiaceae	a	55.6	-	10.2	-
Bromus pectinatus	Poaceae	a	41.6	44.5	16.2	6.8
Tagetes minuta	Compositeae	a	13.9	-	1.24	-
Gallium spurium	Rubiaceae	a	50.0	79.1	8.8	5.2
Bidens pilosa	Compositeae	a	5.6	-	0.1	-
Chenopodium spp.	Chenopodiaceae	a	63.9	77.8	6.2	11.6
Amaranthus hybridus	Amarantheaceae	a	36.1	85.2	5.0	10.9
Plantago lanceolata	Plantagoaceae	a/p	13.9	45	1.51	4.1
Euphorbia spp	Euphoribeaceae	a/p	5.6	-	0.1	-
Polygonum nepalenses	Polygonaceae	a	5.6	37	0.2	2.2
Commelina benghalensis	Commelinaceae	a	25.0	14.8	0.9	3.2
Lolium temulentum	Poaceae	a	5.6	-	0.9	-
Snowdenia polystachya	Poaceae	a	8.3	7.4	0.6	0.5
Agerantum conzoides	Compositeae	a	8.3	11.1	6.4	9.8
Raphanus raphanastrum	Cruciferae	a	8.3	32.2	0.3	0.98
Cyperus blysmoides	Cyperaceae	a	25.0	29.6	8.4	4.1
Medicago sativa	Leguminosae	p	25.0	-	1.3	-
Cynodon dactylon	Poaceae	p	11.1	-	0.4	-
Solanum nigrum	Solanaceae	a/p	-	25.9	-	0.83
Spergula spp.		a	-	11.1	-	0.80

a = annual; p = perennial

- weed species with low density and frequency.

Table 3. Similarity index (%) of weed communities in field pea fields at different locations in the Bale highlands (meher of 1997).

Locations	Sinana	Agarfa	Dinsho
Sinana	100	45.8	56
Agarfa	45.8	100	54.16
Dinsho	56	54.16	100

Table 4. Similarity index (%) of weed communities in faba bean fields at different locations in the Bale highlands (bonna of 1997)

Locations	Gasera	Agarfa	Dinsho
Gasera	100	38.8	40.00
Agarfa	38.8	100	29.40
Dinsho	40.00	29.40	100

Table 5. Similarity index (%) of weed communities in field pea fields at different locations in the Bale highlands (belg of 1997).

Locations	Sinana	Agarfa	Gasera
Sinana	100	47.05	60.97
Agarfa	47.05	100	58.8
Gasera	60.97	58.8	100

Field pea - Genna (belg) season

The major weed species comprised 60% of the weeds infesting the fields. Except for *Bromus pectinatus* and *Digitaria scalarum*, most of the weeds were broadleaf species. *Guizotia scabra* and *Galium spurium* were found frequently, but *Galinsoga parviflora* dominated the fields. These three major weeds comprised about 32% of the weeds in the fields.

Sinana

All the major weed species at Sinana (Fig. 1), except for *Digitaria scalarum,* were broadleaf species. *Digitaria scalarum* was frequent in occurrence. However, *Guizotia scabra,* which comprised about one-fourth of the weeds in the fields, was the dominant species. *Digitaria scalarum* was frequent because farmers gave less attention to land preparation and they use less fertile and exhausted marginal lands for field pea production.

Gasera

All of major weed species at Gasera (Fig. 2), except for *Bromus pectinatus,* were broadleaf species. *Galinsoga parviflora* was the most frequent and dominant weed species, representing about 30% of the infestation. Even though *Guizotia scabra* was similar in occurrence to *G. parviflora, G. parviflora* by far dominated *G. scabra. B. pectinatus* and *Flaveria trinervia* distribution was patchy, showing high infestation levels in restricted areas.

Bona

G. scabra was the most frequent weed, while *B. pectinatus*, which highly infested fields of some districts, was the dominant weed species (Table 2). Two weed species (*Bromus pectinatus* and *Cyperus blysmoides*) comprised more than a quarter of the weeds in the fields.

Sinana

Scorpiurus muricatus was the most frequent weed species. *Cyperus blysmoides,* which highly infested some fields, was the dominant weed species. Even though *C. blysmoides* was not very frequent, it represented one-fourth of the weeds in the fields.

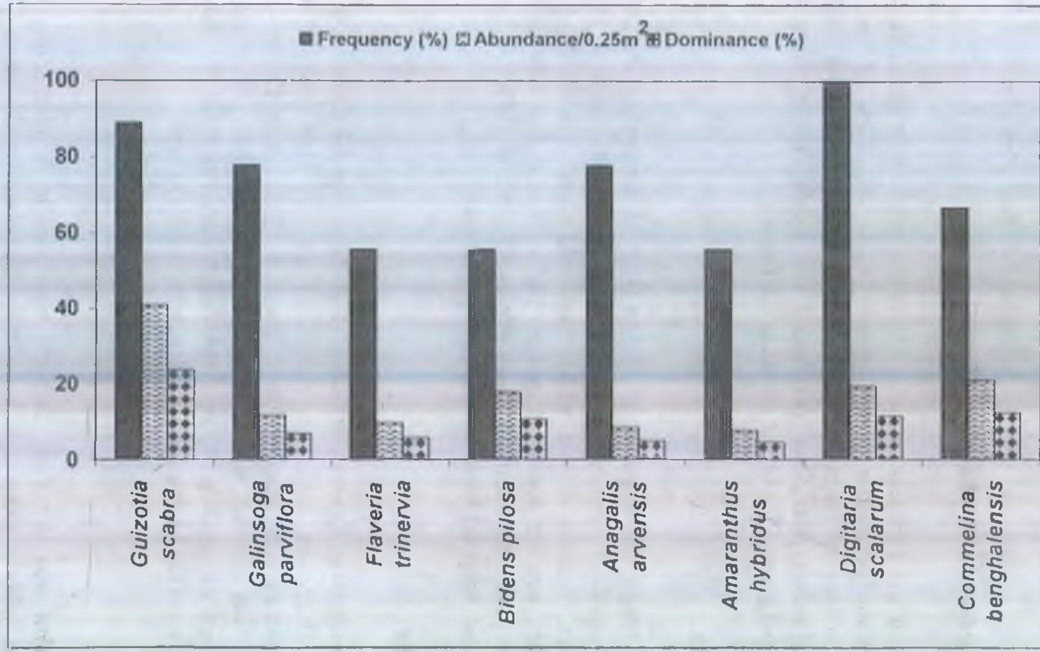

Figure 1. Major weed species in field peas (Sinana district, gana season, 1997.

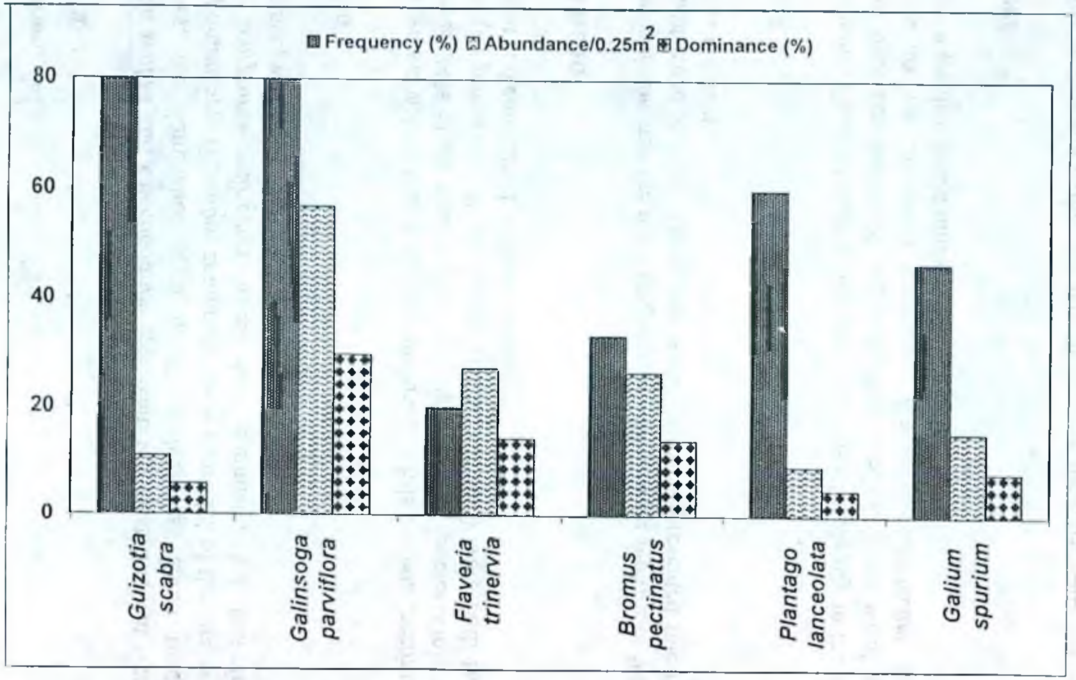

Figure 2. Major weed species in field peas (Gasera district, gana season, 1997).

Agarfa

Guizotia scabra and *Chenopodium* spp. were the most frequent weed species. However, the dominance level of *G. scabra* was about twice that of *Chenopodium* spp. *G. scabra* comprised more than 20% of the total weeds in the fields. *Scorpiurus muricatus* which was dominant, but less frequent in occurrence, was also observed in patches in the fields.

Dinsho

Galinsoga parviflora was frequently observed, while *Bromus pectinatus*, which comprised 24% of the total weeds, was the dominant species. Only three weed species (*G. parviflora, B. pectinatus* and *G. spurium*) were both frequent and dominant and considered as major weeds.

Faba bean

Galium spurium was the most frequent, but *Galinsoga parviflora* was the most dominant weed species. These two weed species represented one-third of the weeds in the fields.

Sinana

Even though *Guizotia scabra* was observed most frequently in the fields, there was no over dominance of any individual species. Some weed species like *Guizotia scabra*, *Scorpirus muricatus*, *Erucastrum arabicum*, and *Galium spurium* were distributed uniformly in the fields.

Gasera

Guizotia scabra and *Galinsoga parviflora* were the most common weed species (Fig. 3). *G. parviflora*, which had an infestation level of about 42%, dominantly infested the fields. The other major weed species were distributed uniformly in the fields without one weed species dominating the others.

Dinsho

Galium spurium was the most frequent weed species, but fields were also highly infested with *Ageratum conzoides*. which only infested the Dinsho district.

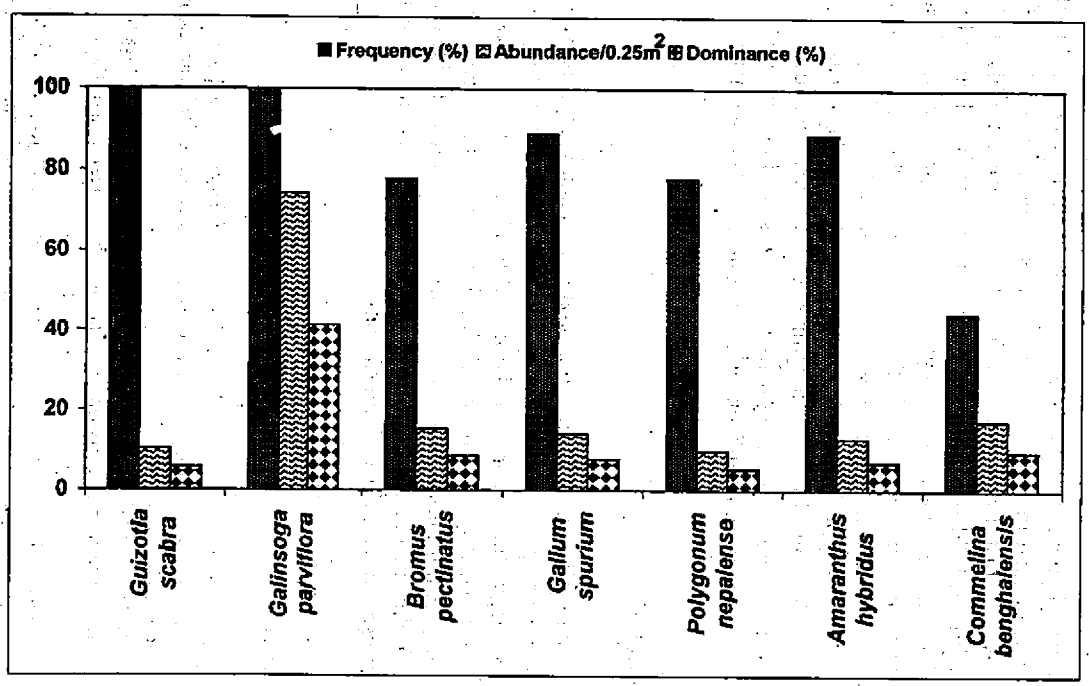

Figure 3. Major weed species in field peas and faba beans (Gasera district, bona season, 1997).

It was observed that the most frequent weed species are dominant and abundant, but occasionally, less frequent weed species could be dominant or vice versa. This happened when a weed species was specific to one area and only dominant in that locality and was absent from the other sites. For example, *Cyperus blysmoides*, *Bromus pectinatus*, and *Ageratum conzoides* were dominant in some districts, but less frequent over all.

Farmers' management practices for field pea and faba bean

Most farmers in the surveyed areas weed faba bean fields once, but they do not weed fields planted to field pea at all because they often consider field pea as competitive against weeds. In addition, farmers use unfertile and exhausted cereal fields for field pea, but they allocate area near their homes for faba bean production. Farmers give more attention to land preparation for faba bean than for field pea. No fertilizer is applied for either field pea or faba bean production. However, farmers often use fields which were planted to barley during the ganna (belg) season for field pea production in the bona (meher) season, i.e., double cropping. This minimizes the ploughing requirements and results in a double cropping and crop rotation system. As a result, field pea and faba bean production is more commonly encountered during the bona (meher) season.

Conclusion

Most of the major weed species are broadleaf species, especially in faba bean fields. Weed composition varied across locations, seasons and crops. Any weed control strategy should consider the major weeds as target species, particularly the dominant weed species in specific localities. Since frequency, abundance and dominance are not indicators of yield losses, it is important to identify threshold levels for the major weed species. It is important also to consider farmers' practices used to reduce weed infestations.

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On-farm evaluation of post-emergence herbicides for the control of *borren* in barley

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Abstract

An experiment was carried out to evaluate the effectiveness of Starane M and Brittox against *borren* and other broad leaf weeds. The trial was superimposed on farmers' fields in Wogera, Dabat and Debark weredas of north Gonder. The combined statistical analysis over locations showed significant ($p<0.5$) grain yield difference among the treatments and locations. Brittox gave the highest mean grain yield increase of 48% (581 kg/ha) and 17% (307 kg/ha) over the unweeded check and farmers practice, respectively. On the other hand, Starane M was superior against the weed (87% control) compared to Brittox (65% control). However, minor toxicity effect was observed following starane M application. Brittox gave the highest net benefit (1429 birr/ha) followed by farmers practice (1360 birr/ha) and Starane M (1185 birr/ha). The marginal rate of return in shifting from weedy check to farmers practice was 640%. Farmers appreciated the effectiveness of the herbicides, specially Starane M. The practical problem encountered was that *borren* emerges continuously from July to September but the chemicals were applied once, at the end of July, and were ineffective on the new flush of emergence late in the season. Hence, further investigation need to be made in order to understand the biology of the weed and explore other alternative control methods.

Introduction

Duragna, a mixture of barley and wheat, and sole barley are dominant crops in Wogera, Dabat, and Debark weredas. High weed infestation, particularly a weed locally called *Borren (Chrysanthemum segetum)* is one of the major production constraints in the area (1). According to farmers, *borren* was introduced during the Italian invasion, in 1935. Italians brought it as a horse feed. It was first observed at Gotit (Debark) and Ambagiorgis (Wogera), the first settlement areas of Italian soldiers. The initial infestation remained restricted to the area for 30 to 40 years. The weed spread, covering nearly all of the three weredas, over the last 20 years.

Borren is locally known under different vernacular names i.e. *Metelem, Ager Atifa, Gimkite, Menati kitel, Yegotit Abeba, Borren Tesfu and Abebaw Dessie.* Tesfu in Mikara, Dabat and Dessie in Gomia, Debark weredas were the first two farmers who introduced *borren* to their respective localities, through seed. The name *borren* is derived from its beautiful flowers. In the locality, *borren* is called *Bukidadie* meaning attractive but noxious.

Borren is a broad leaf plant and has numerous fibrous roots with high tillering capacity. It is a weed of both arable and non arable land (3). The seed is small with long period of dormancy, upto 15 years. The weed is prolific seed producer, on average 49000 seeds/plant. It is easily disseminated by crop seed, flood, animal dung, animal hoof and wind. *Borren* has now spread further to Yilmana Densa, 260 km south of its native place possibily through animal dung, because the area used to be a market center. It grows nearly in all soil types but is more severe in red to gray soils with poor fertility. It is common to see abandoned fields due to the weed in such localities. *Borren* is a very vigorous and aggressive annual weed (3). It can grow up to 1 meter height depending on the fertility status of the soil.

The weed can not be fully removed manually and regenerates within one to two weeks after weeding. It emerges late and farmers allow it to grow until it becomes possible to pull out by hand. Some farmers, however, are very reluctant to weed their crop after flowering and therefore let *borren* set seed and spread. The problem is being aggravated from time to time. Farmers express their frustration through sayings such as "*Addis Abeba yabibal gena*" meaning no matter what they do the resilent weed will flourish and invade their fields. Currently, farmers attempt to control *borren* through frequent plowing and weeding, burying or burning weeded plants and fallowing. Farmers also take caution not to purchase seed from infested areas.

Borren is preferred as a feed for livestock at its vegetative stage. Palatability seems to decrease at maturity. At harvest, farmers mix *borren* and crop straw to improve feed quality.

There was little work done, so far, on *borren* control except some herbicide observation trials conducted by Wogera Wereda Agricultural Bureau and Adet Research Center. The former reported that 2,4-D was not effective because it only killed the aerial parts. Starane M, Brittox and 2,4-D resulted in 90%, 80% and 53% control respectively at Adet (4). Hence, based on available information, a trial was initiated to evaluate the efficacy of the above chemicals against *borren* and other major broadleaf weeds on farm.

Materials and Methods

Two broadleaf, post-emergence, herbicides (Starane M and Brittox) were compared with farmers' practice in Wogera, Dabat and Debark weredas for two years (1995 - 1996). A total of 7 sites were used (elevation 2700-2900 m.a.s.l). However, conclusive data was obtained from 6 sites. Starane M and Brittox were applied at the rate of 3.0 and 2.5 l/ha, respectively.

The trial was superimposed on barley fields and was laid out in RCBD with two replications and a plot size of $50m^2$. Herbicides were applied one month after planting at the early tillering stage of the crop. Farmers practice consisted of single weeding, two months after planting. Farmers allow *borren* to grow till they can be able to pull it out by hand.

Weeds were counted before and after spraying using a 50cm x 50cm quadrat. Grain yield was taken from a net plot size of $16\ m^2$. Labor data, wage rate, price of barley grain and chemicals were collected. Partial budget analysis was carried out following CIMMYT's guideline (2).

Results and Discussion

The herbicides have shown good potential against *borren*. Starane M and Brittox resulted in a mean of 87% and 65% control. Complete suppression of the weed by Starane M at AmbaGiorgis was particularly impressive (Table 1).

Heavy and continuous rain, soon after spraying, has led to considerable reduction in the efficacy of the chemicals especially at Meskelko site. New emergence of *borren* was observed later in the season almost in all sprayed plots. In general, both chemicals considerably suppressed most of the broadleaf weeds, including *borren*.

Brittox gave the highest yield of 1783 kg/ha, which was 48% over the unweeded check (Table 2). Starane M and farmers practice resulted in similar yield increment of 19% and 23% respectively. In most of the sites, Starane M effected superior control against the weed but, also showed considerable toxicity that led to reduced yield. This was because of the very high rate of 3 l/ha which was used erroneously. The recommendation was 2.25 l/ha.

According to the results of portial budget analysis, Brittox gave the highest net benefit of 1429 birr/ha followed by farmers practice (1360 birr/ha) and Starane M (1185 birr/ha) Table 3. The marginal rate of return in shifting from weedy check

Table 1. Mean *borren* shoot count before and after herbicide application, 1995-1996

Site	Starane M			Brittox		
	Before	After	% control	Before	After	% control
Meskelko	57	32	44	59	26	56
Jagrie	41	3	93	48	24	50
Gombaye	200	20	90	215	67	69
Tegora	100	11	89	69	10	86
A/Giorgis	259	0	100	150	83	45
Dildy	85	28	67	129	16	88
Mean	132	16	87	110	38	65

Table 2. The effect of different weed control methods on the grain yield (kg/ha) of Barley in North Gonder, 1995 - 1996

Treatment	Meskeliko	Jagrie	Gombaye	Tegora	A/Giorgis	Dildy	Mean
Starane M	1153	2099	1173	792	1822	1569	1435
Brittox	1980	2550	1387	1233	1803	1744	1783
Farmer practice	1140	2304	1830	482	1862	1241	1476
Unweeded	1250	1509	1391	536	1466	1063	1202
Mean	1381	2115	1445	761	1738	1404	

Table 3. Partial budget analysis of alternative weed control methods

Item	Treatment			
	Starane M	Brittox	Hand weeding	Unweeded check
Average yield (kg/ha)	1435	1783	1476	1202
Adjusted yield (kg/ha)	1291	1605	1328	1082
Gross benefit (birr/ha)	1356	1685	1395	1136
Cost of herbicide (birr/ha)	165	250	0.00	0.00
Cost of spraying (birr/ha)	6	6	0.00	0.00
Cost of hand weeding (birr/ha)	0.00	0.00	35	0.00
Total cost (birr/ha)	171	256	35	0.00
Net benefit (birr/ha)	1185	1429	1360	1136
Marginal rate of return		100%	640%	----

Note: Yield is adjusted by 10%
Price of Starane M = 165 birr/l
Price of Brittox = 99.99 birr/l
Price of barley grain = 105 birr/qt
Local wage rate = 5 birr/day

to farmers practice was 640%. Farmers can earn 6.40 birr for every birr invested on hand weeding. Farmers can also earn a marginal rate of return of 100% in shifting from their practice to using *Brittox*. This is, however, low compared to the minimum acceptable rate of 120% in most parts of Northwest Ethiopia.

Farmers appreciated the effectiveness of the herbicides especially Starane M. The chemicals were more efficient on *borren* which was difficult to up root and was capable of regenerating soon after hand weeding. Farmers noted that herbicides are expensive but exhibit obvious advantage over manual weeding which seems to encourage more resprouting of *borren* shoots. The unacceptable level of toxicity of Starane M to the crop was, however, disappointing to farmers.

Conclusion

Both chemicals showed good potential against *borren*. Brittox gave the highest yield and net benefit compared to other treatments. There was no appreciable yield difference between farmers practice and Starane M. The practical problem encountered was the continuous emergence of *borren* from July to September which could necessitate repeated use of chemicals. Hence, further research is needed to understand the biology of *borren* and explore other alternative control measures. Furthermore, the weed is a serious production constraint in the area and thus extension and local officials need to mobilize farmers for eradication campaigns.

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Evaluation of pre-emergence herbicides for the control of *Parthenium hysterophorus* in sorghum

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Abstract

Efforts to manage *Parthenium hysterophorus* have been minimal in spite of its wide distribution and intensity, and the serious economic losses it is causing on major crops grown in the eastern parts of Ethiopia. Hence, a preliminary investigation was conducted to determine the effectiveness of four pre-emergence herbicides and two hand weedings under field conditions at the Werer Research Center. Results revealed that both Gesaprim Combi (5.5 l/ha) and Primextra TZ 500 FW (5.0 l/ha) were found to be the most effective in controlling *Parthenium* for a prolonged period after application. They significantly reduced the weed population in terms of count and biomass, and increased sorghum grain yield compared to the unweeded check. Among the tested chemicals, therefore, both products have potential for use in sorghum.

Introduction

Parthenium hysterophorus L. has become an increasingly serious problem in major crops in eastern parts of Ethiopia in addition to being a major problem on range lands and waste lands. Previous reports indicated that although the prevalence and distribution of the weed was extremely high, the infestation is minimal in arable lands. Even then, several hectares of agricultural and range lands in the eastern part of east Hararghe were infested by this pernicious weed (1).

Currently, the weed is spreading at an incredible pace and is heavily infesting most agricultural areas, range lands and waste lands in the affected region. It has also recently spread to eastern Shoa, and southeastern and northern parts of Ethiopia. This is partly attributed to the high reproductive and dissemination potential of the weed. It seems also that the unsightly expansion and prolific growth on non-arable lands permits the weed to colonize large expanses.

The problem of *Parthenium* also seems to be spreading very fast as confirmed by reports of its occurrence in previously unaffected areas or regions of the country. It is causing the same problem regardless of the crops grown. It competes with crops for water and mineral nutrients. Furthermore, it releases chemicals into its immediate environment that are toxic to other plants; therefore, its harmful effects exceed competition alone. As a result, vigorous crop growth is impossible on land infested with *Parthenium* (3). Although there is no quantified data on the extent of yield losses incurred due to *Parthenium* infestation in sorghum fields, as well as in other crops, it is reportedly serious. It has been reported that the weed can considerably reduce yield in crops through the allelopathic properties of its abundantly produced pollen (5).

In spite of the recognized importance of *P. hysterophorus* in the country, almost no control alternatives are available. Manual labor is the only control practice used by farmers to manage the weed in agricultural areas. As the weed causes contact dermatitis, asthma and fever to human beings, hand weeding is not advisable. Besides, hand weeding is costly as it requires frequent operations owing to the emergence pattern of the weed (6). Hoeing can also be used but repeated operations are needed as long as weed seeds exist in the soil. Some studies in India (4) have shown that repeated cultivation is less effective than control by chemicals. Furthermore, chemicals could offer a valuable option to economically control the troublesome weed (2). Hence, it is considered important to screen a range of herbicides. This paper, therefore, presents the results of a preliminary evaluation conducted to select safe and effective herbicides for use in sorghum.

Materials and Methods

The trial was established on fields infested naturally by *Parthenium* at Werer Research Center in 1997/98. The treatments comprised four herbicides, two hand weedings and an unweeded check. Details of the treatments are listed in Table 1.

The experiment was laid out in randomized complete blocks with four replications. The plot size was 4 x 4 m. The sorghum variety 76 T_1# 23 was used. Weed counts and weed biomass were recorded using a 0.25 x 0.25 m iron rod quadrat randomly dropped to collect four samples per plot. Stand count at harvest, head weight and grain yield were recorded. Scoring crop phytotoxicity was performed using a 1-9 scale. Weed counts were transformed by the square root method and weed biomass by the logarithmic method before analysis to normalize the data. Statistical analysis of the data was done using the MSTAT-C program, and means were tested for difference using the LSD test.

Table 1. Weed control treatments applied to sorghum.

	Trade name	Common name and active ingredient concentration (g/l)	Recommended rates of products (kg or l/ha)
1.	Dynam 500 FW	atrazine + flumetralin (350 + 200 g/l)	5.5
2.	Primextra TZ 500 SC	terbuthylazine + metolachlor (200 + 300 g/l)	5.0
3.	Gesaprim Combi	atrazine + terbutryn (250 + 250 g/l)	5.5
4.	Stomp	pendamethalin (330 g/l)	4.0
5.	Hand weeding twice	--	--
6.	Unweeded check	--	--

Note: all herbicides used in this trial are Novartis products.

Results and Discussion

The results have shown that there was a significant difference between the herbicides applied in terms of effect both on the *Parthenium* weed population and weed biomass (Table 2). The lowest weed population was observed on plots sprayed with Primextra TZ 500 FW which was equal to Gesaprim Combi, followed by Dynam 500 FW. Consequently, these herbicides significantly reduced the dry weed biomass compared to the other treatments. Conversely, significantly increased *Parthenium* pressure and weed biomass was recorded with Stomp and the weedy check. On the other hand, Stomp significantly reduced the biomass weight of other weed species (46.8 g/m^2) compared to the other chemicals.

It is worth noting here that both Primextra TZ 500 FW and Gesaprim Combi effectively suppressed the emergence of *Parthenium* for more than two months after application. Similarly, Dynam 500 FW remained effective for a reasonably long period. Generally, overall weed control was adequate for these chemicals, requiring no supplementary operations for late emerging weeds until harvest of the crop.

Treatment effects were highly significant for the crop parameters considered (Table 3). The differences in stand count of sorghum were significant. Plots sprayed with Stomp significantly reduced the crop stand count (35.5 plants/plot) showing a phytotoxic effect. The other chemicals also showed a slight phytotoxicity even though their effect on stand count was not significant. In view of the serious economic and social effects of the weed, this low phytotoxicity could be considered an advantage as the herbicides can be used with care to control the weed effectively. In pot experiments on maize and sorghum, the maize crop showed better tolerance to the herbicides, reflecting the relative safety of herbicides for use in maize versus sorghum. Results of a simple correlation analysis revealed that sorghum grain yield was negatively correlated with the level of the *Parthenium* population and phytotoxicity but exhibited a positive and significant relationship with plants/m^2 and head weight (Table 4).

Regarding head weight and grain yield, there were no statistically significant differences between Primextra TZ, Gesaprim Combi, Dynam and twice hand weeding; these treatments were superior to Stomp and the weedy check. The highest head weight (3504 g/plot) and grain yield (26.7 qt/ha) of sorghum was obtained from twice hand weeding. On the contrary, the lowest head weight (508 g/plot) and grain yield (0.4 t/ha) was obtained from the unweeded check. This is mainly attributed to the heavy *Parthenium* infestation that reduced head weight per stand of the crop and that in turn had a direct effect on total head weight and grain yield of sorghum.

Table 2. *Parthenium* weed count, biomass and total weed biomass after treatment.

Treatment	Rate (kg/ha)	*Parthenium* Count (no./m^2) 30 DAE	60 DAE	Dry biomass (g/m^2)	DBW (g/m^2)
Dynam	5.5	0.0	72.6 (8.52)*	8.40 (0.80)**	275.3 (2.36)**
Primextra	5.0	0.0	18.8 (4.13)	0.00 (0.00)	562.8 (2.75)
Gesaprim Combi	5.5	0.0	20.8 (4.42)	0.00 (0.00)	262.4 (2.39)
Stomp	4.0	97.6	135.2 (11.36)	144.00 (2.13)	44.8 (1.56)
Hand weeding 2x	--	217.6	32.4 (5.55)	46.80 (1.61)	163.6 (2.20)
Weedy check	--	155.6	184.4 (13.47)	1159 (3.04)	842.0 (2.89)
Mean		7.91	1.26	2.36	
CV(%)		0.38	20.91	8.40	
LSD (5%)		2.43	0.40	0.30	
LSD (1%)		3.36	0.55	0.41	

*, **: figures in parentheses are square root and log transformed values, respectively.

DAE: days after emergence.

DBW: total dry biomass weight of other weed species.

Table 3. Effect of treatments on stand count, head weight and grain yield of sorghum.

Treatment	Rates (kg/ha)	Stand count (no./plot)	Head wt. (g/plot)	Grain yield (qt/ha)
Dynam	5.5	61.00	3075	24.2
Primextra	5.0	55.50	2763	20.0
Gesaprim Combi	5.5	75.75	3207	24.7
Stomp	4.0	35.50	1272	7.2
Hand weeding twice	--	67.50	3504	26.7
Weedy check	--	26.25	508	4.0
Mean		55.58	2388	17.8
CV(%)		18.19	28.96	27.98
LSD (0.05)		14.69	1042	7.50
LSD (1%)		20.30	1441	10.36

Note: hand weeding at 25-30 and 55-60 days after emergence

Table 4. Results of simple correlation analyse.

Characters	Grain yield
Phytotoxicity	-0.577 NS
Weed population/m^2	-0.729 NS
Crop stand at harvest (no./m^2)	0.851*
Head weight (g)	0.974**

*, **: significant at the 5 and 1% levels, respectively.

NS: non-significant at the 5 % level.

Conclusion

The results clearly showed that Gesaprim Combi (5.5 l/ha) and Primextra TZ 500 FW (5.0 l/ha) followed by Dynam 500 FW (5.5 l/ha) incorporated pre-emergence showed conspicuous effects on *Parthenium* emergence and resulted in a significant reduction in *Parthenium* biomass. As these chemicals showed a slight phytotoxicity, optimum rates should be used or the sorghum crop should be treated with a safener in case the rates mentioned are used directly. Some of these herbicides have been replaced by more current versions. It is, therefore, proposed that optimum and economically feasible rates for the new versions should urgently be determined for use against this noxious weed.

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Assessment of cowpea yield loss due to weeds in the central rift-valley of Ethiopia

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Abstract

A field experiment was conducted on cowpea to asses the yield loss incurred due to weeds and determine the critical period of weed competition. The critical period of weed competition was 2-4 weeks after crop emergence. One hand weeding at trifoliate stage was essential to obtain optimum yield of the crop. The two test varieties were highly sensitive to weed competition. Though, the semi-erect type (White wonder trainling) was more susceptable than the erect type (Black eye bean) at all the three test sites.

Introduction

Cowpea *(Vigna unguiculata L. Walp.)* is one of the economicaly important food grain legumes. The crop was domesticated in West Africa (Marichal, 1985). It is becoming increasingly important in the whole of Sub-Saharan Africa. This may be partly due to the ability of the crop to produce reasonable yield in areas with limited rainfall, as low as 200 mm per annum (Marfo et al, 1997).

Cowpea is recognized as a good quality protein source and thus an important component of the diet of many people in Africa. Economic value of the crop has also long been appreciated, particularly as hardy crop to be relied on during the " hunger season" (Aykroyed and Doughty, 1964).The nutritional value of cowpea lies in its high protein content (20-25%) which is double the amount obtained from most of the cereals (Santon, 1966).

Currently research emphasis has been given to cowpea as an important food legume crop, grown in the arid and semi-arid, low rainfall, area of the central rift valley.

Prostrate, spreading, climbing and dwarf varieties are cultivated and used as grain, vegetable, fodder and green manure (Florence et al., 1984). Cowpea has

Prostrate, spreading, climbing and dwarf varieties are cultivated and used as grain, vegetable, fodder and green manure (Florence et al., 1984). Cowpea has great potential to be used as local food i.e. *Shiro* and *Niffro,* in the absence of haricot bean, in the lowlands of Ethiopia.

Substantial yield loss was recorded due to weed infestation on cowpea. The crop is usually susceptible to weeds especially during seedling stage.

Although cowpea is more competitive to weeds than other legumes, considerable variation has been observed between varieties depending upon plant height and leaf area. Field trials have shown that uncontrolled weed competition may reduce yield by 50% or more, compared to a weed-free crop. Most farmers practice hand pulling and hoeing but this is often done too late to prevent serious losses and hired labor may be unavailable at the right time (COPR, 1981).

Weed-crop competition during the first 30 days after crop emergence is reported to be critical for most crops (Zimdahl, 1980). Knowledge about the critical period of competition is important for the development of appropriate weed management strategies since it is neither economic nor feasible to keep a crop weed-free all season (Kumuwenda et al, 1994). Thus, the experiment was conducted with the objective to assess yield loss incurred on cowpea due to weed competition and to find out the most critical period of competition between weeds and two cowpea varieties.

Materials and Methods

The experiment was conducted in three different locations: Melkassa Research Centre and on farmers' fields at Wolinchiti and Ziway, in 1997 and 1998. The trial was laid out in randomized complete blocks with four replications in a split plot arrangement. The plot size was 3m x 3m and spacing between rows and plants was 60cm and 20cm, respectively. The two cowpea varieties, Black eye bean (erect type) and White Wonder Trailing (semi erect) were in the main plots and the different weeding treatments were in the sub-plots. The sub plot treatments were:

1. Unweeded (check)
2. Repeated weeding the whole season
3. Hand weeding once at first trifoliate stage of the crop
4. Weeding twice, at first trifoliate + pod formation stages
5. Weeding at pod formation stage
6. Weeding twice, at pod formation + pod filling stages
7. Weeding once at pod filling stage.

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Results and Discussion

Major weed species identified across the trial sites are listed in Table 1. Both the semi-erect type and erect type cowpea varieties were sensitive to weed competition mostly suffering over 60% loss across years and locations when weeds were allowed to grow for the whole season Table 2, 3 and 4.

Significant and almost three fold yield increase was achieved when the crops were kept weed free or atleast weeded early compared to the check (no-weeding). There was no significant yield difference between the early weeding treatments and repeated weeding for the whole season; suggesting that the critical time weeds have to be removed, to obtain maximum yield, is during the early growth stage i.e. 2-4 weeks after emergence. In most cases once weeding at the trifoliate stage was sufficient to achieve optimum yield. Late weeding led to yield reduction, partly due to the mechanical damage inflicted on the crops particularly to the semi-erect type.

White wonder trailing yielded relatively higher than black eye bean although it was mostly more sensitive to weed competition than the latter.

Table.1 Major weeds at the three trial sites.

Melkassa	Wolinchiti	Ziway
Eragrostis aspera	*Commelina benghalensis*	*Galinsoga parviflora*
Nicandra physalodes	*Foenicum vulgare*	*Argemone mexicana*
Amaranthus hybidus	*Cyperus spp.*	*Nicandra physalodes*
Erucastrum arabicum	*Digitaria abyssinica*	*Erucastrum arabicum*
Convolvulus arvensis	*Sorghum arundenanceum*	*Convolvulus arvensis*
Commelina benghalensis	*Eragrosts aspera*	*Sorghum arundenanceum*
Argemone mexicana	*Erucastrum arabicum*	*Eragrostis aspera*
Cyperus spp	*Argemone mexicana*	*Commelina benghalensis*
		Cyperus spp.
		Flaveria trinervia

Table 2. Effect of time of weeding on cowpea yield at Melkassa

Treatment	Yield (kg/ha)			
	1997		1998	
	Black eye bean	White wonder trailing	Black eye bean	White wonder trailing
1. Repeated weeding for the whole growth period	1543	1633	1183	1900
2. Weeding at first trifoliate	1538	1460	1263	1968
3. Weeding at first trifoliate + pod formation	1492	1528	1330	2010
4. Weeding at pod formation	596	722	655	930
5. Weeding at pod formation + pod filling	654	833	785	1135
6. Weeding at pod filling	551	592	550	820
7. Un weeded (check)	516	430	318	665
CV %	23.02		21.41	
LSD 5%	332.2		340.1	

Table 3. Effect of time of weeding on cowpea yield at Wolenchiti

Treatment	Yield (kg/ha)			
	1997		1998	
	Black eye bean	White wonder trailing	Black eye bean	White wonder trailing
1. Repeated weeding for the whole growth period	1013	1159	1498	1600
2. Weeding at first trifoliate	950	1095	1145	950
3. Weeding at first trifoliate + pod formation	929	986	1523	1653
4. Weeding at pod formation	432	329	895	1183
5. Weeding at pod formation + pod filling	335	265	805	1150
6. Weeding at pod filling	328	151	810	618
7. Un weeded (check)	320	87	278	288
CV %	24.67		33.05	
LSD 5%	211.7		487.3	

Table 4. Effect of time of weeding on cowpea yield at Ziway

Treatment	Yield (kg/ha)			
	1997		1998	
	Black eye bean	White wonder trailing	Black eye bean	White wonder trailing
1. Repeated weeding for the whole growth period	1480	1310	1079	1433
2. Weeding at first trifoliate	1344	1194	871	1443
3. Weeding at first trifoliate + pod formation	1253	1190	1013	1270
4. Weeding at pod formation	792	513	683	1095
5. Weeding at pod formation + pod filling	782	541	588	942
6. Weeding at pod filling	651	470	606	885
7. Un weeded (check)	553	456	351	615
CV%	18.70		116.61	
LSD 5%	240.3		425.1	

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Weed incidence and control in the major crops at Assosa: An overview

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Abstract

Assosa is one of the high rainfall, humid and warmer areas in the country. Therefore, weeds grow vigorously and are serious setbacks to crop production in the area. Mostly farmers cannot cope with the management of weeds in their crops. Thus, output of crops suffers seriously. Noxious weeds recorded in the area were: (grassy) *Eleusine indica*, *Digitaria ciliaris*, *Eragrostis aspera* and (broadleaved) *Guizotia scabra*, *Commelina subulata*, *Amaranthus* spp., *Bidens* spp., *Polygonum nepalense* and *Celosia trigyna*. At Assosa Research Center nine experiments have been conducted mostly on hand weeding and hoeing and some on chemical control on maize, sorghum, tef, hot pepper, haricot bean and soybean. Results indicate that weeding maize twice at 20-25 and 40-45 days after planting gave the best yield and the highest marginal benefit. The presence of weeds for the first six, nine, and twelve weeks after sowing and the entire growing season in maize recorded an estimated yield loss of 36, 61, 80 and 85%, respectively. The critical time of sorghum weeding lies from the third to seventh weeks after planting. Continuous removal of weeds up to 75 days gave the highest biological yield. Season long competition of weeds in hot pepper incurred 94% yield loss and 45 to 87% losses were recorded from one or two weeding treatments. For less mechanical damage, ease of handling and reduced costs of weeding of tef, one weeding between 35-40 days after sowing appeared to be sufficient. Chemical control of maize was found economical as compared to hand weeding and hoeing. Alachlor plus atrazine at the rate of 1.25 + 1.25 kg a.i./ha gave the highest maize grain yield. In sorghum, hand weeding was observed to be better than herbicide spraying. For better productivity of the major crops in Assosa area, especially maize and sorghum, a concerted effort should be directed towards improved weed management.

Introduction

Assosa is one of the high rainfall, humid and warmer areas in Ethiopia. Therefore, weeds grow vigorously and seriously reduce crop productivity in the area. Different crops have characteristic weeds. Cultural operations associated with the growing of a crop together with the rotation effect may be such as to encourage or discourage specific weeds (5). Weed control aims to decrease weed density below the critical threshold level (11). The major crops in Assosa area are maize, sorghum, tef from cereals; haricot bean and soybean from pulses; noug from oil crops; hot pepper and sweet potato from horticultural crops (2). The major production constraints in the area were reported to be lack of improved varieties, pest problems (weeds, insects and diseases), lack of optimum crop management practices and poor soil fertility. Weeds are very serious menaces especially in areas where frequent and deep cultivations are exercised. In some weedy years, farmers cannot cope with weed management. Therefore, output of crops reaches nearly to zero. To tackle this problem, nine studies were launched mainly on maize, tef, sorghum, hot pepper, haricot bean and soybean. Annual weeds were observed to be aggressive and chemical control studies were found to be profitable as compared to hand weeding.

Inefficient weed control is one of the main factors causing the low average yield of maize in East Africa (1). Experiments carried out at Awassa, Bako and Nazret for three consecutive years indicated an average yield reduction of 83-100% of hot pepper (8).

Because of its growth habit, tef is a poor competitor with weeds for nutrient, light and soil moisture (4). Even under more favorable moisture relations, one weed per 61 cm of row reduced sorghum yield approximately 40% and one per 30 cm reduced it more than 50%; weeds germinating with the crop were detrimental (12).

Materials and Methods

A. General survey and identification of weeds

A general survey of weeds in major crops was appraised at a 25 km radius in four directions taking Assosa Research Center as a pivot. Samples were administered and identifications were made in reference to illustrated manuals. Confirmation of weed species were conducted by Mr. Chris Parker (weed research consultant) who was stationed at Holetta.

B. Crop-weed competition studies

Crop	Fertilizer N/P_2O_5 (kg/ha)	Variety	Duration (years)	Spacing (cm)	Seed rate
Maize	75/75	KCB	3	75x30	25
Tef	25/25	local	3	broadcast	30
Hot pepper	100/100	Bako local	3	70x30	1
Sorghum	75/75	Is 9302	1	75x15	7

Time and frequency of weeding were evaluated based on: 10 treatments for maize (20-25, 20-25 and 40-45, 20-25, 40-45 and 60-65, 20-25, 40-45, 60-65 and 80-85, 40-45, 60-65 and 80-85, 60-65 and 80-85, 80-85, 60-65, 40-45 and no weeding); 11 treatments for tef and hot pepper (15-20, 35-40, 55-60, 80-85, 15-20 and 35-40, 35-40 and 55-60, 55-60 and 80-85, 15-20, 35-40 and 55-60, 35-40, 55-60 and 80-85, 15-20, 35-40, 55-60 and 80-85 and unweeded check); 18 treatments for sorghum (15, 30, 45, 60, 75, 90 days after sowing weed infested and weed free, 15 and 30. 15, 30 and 60, 15, 30, 60, 90 days after sowing hand weeded plots, weed free the entire season and weedy check). In addition, 20 kg/ha atrazine was applied as a pre-emergence herbicide both to the crop and the weed for comparison).

The design was a randomized complete block in four replications. Height, population density and yield of the crop was recorded and a partial budget was calculated. Moreover, weeds were counted four times in all plots just before each weeding time.

C. Chemical weed control

a. Maize: Five chemicals (atrazine, metolachlor, alachlor, pendimethalin and terbutryn) at different doses and in various combinations were compared with manually weeded and unweeded checks. Spraying was done one day after sowing (calibrated at a spray volume of 690 ml). Variety for the study was Bako Composite.

b. Sorghum: Treatments were atrazine at 1.5 and 1.75 kg a.i/ha, alachlor+atrazine 0.75+1 and 1+1.25, atrazine+pendimethalin 0.75+1.37 and 1+1.5, atrazine+terbutryn 1+1 and 1.25+1.25, metolachlor 0.96, alachlor 1.29, pendimethalin 1.5 and terbutryn 2 kg a.i./ha. In general, 14 herbicide treatments were compared to the weeded and unweeded check. Spraying was done two days after planting (calibrated at 555 ml/plot). Variety for the study was IS 9302.

Weeding was done with the local hoe. Design was randomized complete block with four replications. Plot area: main 3.75 x 5.1 gross and 2.25 x 5.1 m net, (control strip was 1.5 x 5.1 m). Supplementary slashing was done. Type and density of weeds was counted once at the third week after emergence of the crops with a 0.25 m^2 quadrat. General and individual weed controls were subjectively judged on a 0-100% scale and the crop health/damage (phytotoxicity) was scored on a 1-9 scale on the 29^{th} and 88^{th} day after planting for maize and 31^{st} and 90^{th} days for sorghum. The economics of supplementary slashing was also computed.

Results and Discussion

From the general survey, seven grassy and 19 broad-leaved weeds were identified as important of arable crops weeds (Table 1). All the noxious weeds were annuals. These were: from (grassy) *Eleusine indica, Digitaria ciliaris, Eragrostis aspera* and (broad-leaved) *Guizotia scabra, Commelina subulata, Amaranthus* spp., *Bidens* spp., *Polygonum nepalense* and *Celosia trigyna*.

All studies except the tef trial indicated that weed competition had a great impact on the yield of crops. Very little variation on grain yield, tiller number, plant height and population density of tef was obtained among weeding treatments and this was attributed to the low level of weed infestation at the experimental site. No weeding was found to be economically advantageous (Table 2). From the view of less mechanical damage during weeding, ease of hand pulling and reduced costs of weeding, one weeding between 35 and 40 days appeared to be sufficient for tef (7).

Competition of maize with annual weeds was found to be severe during the first six weeks of crop growth. Weeding twice at 20-25 (three weeks) and 40-45 (six weeks) followed by four and three weedings at three weeks interval after sowing gave the best yield and the highest marginal benefit (Table 3). Weeding cost increased and grain yield of maize declined as the time of weed removal was delayed. Plant height and population of maize showed a response to weeding treatment similar to that of the grain yield (Table 4). The presence of weeds for the first six, nine, and twelve weeks after sowing and for the entire growing season of maize resulted in estimated yield losses of 36, 61, 80 and 85%, respectively. Since manual weeding is inefficient in areas where perennial weeds are abundant, the combined use of hand pulling and hoeing with oxen or tractor cultivation and other practices should be encouraged (6).

Hot pepper was a poor competitor with weeds (3). Season long competition of weeds incurred 94% yield loss; 45 to 85% losses were also recorded from one or two weeding treatments (Tables 5 and 6). The influence of timing on input costs of weeding was much higher than the frequency of weeding. With a delay in the removal of weeds, the manual labor needed for weeding was increased.

Table 1. Weeds on major crops in the Assosa area[a].

Weed				
Scientific name	Vernacular name	Host crops	Status	Remark
Eleusine indica		Maize, sorghum, tef, hot-pepper, h. bean, soybean	Noxious	Serious on major crops Dominant early season
Digitaria ciliaris		Maize, sorghum, tef, hot-pepper, h. bean, soybean	Noxious	Second noxious grassy weed
Eragrostis aspera	Yewusha tef	Tef, hot pepper	Noxious	Predominant in late season
Setaria pumila	Asendabo	Maize, sorghum	Moderate	Resists atrazine
Commelina subulata		Soybean, h. bean, maize, sorghum, tef	Noxious	Predominant starting from end June
Commelina benghalensis	Wof Ankur	Sorghum, maize, hot pepper	Moderate	
Guizotia scabra	Metch	All major crops	Noxious	Predominant after grassy weeds removed and in frequent hoeing
Bidens setigeta, B. prestenaria B. pilosa	Adei Abeba	All major crops	Noxious	Very serious in Komeshiga area
Amaranthus lividus, A. graciziense	Aluma	All major crops	Noxious	From early June to end August
A. hybridus		Horticultural crops	Moderate	Important September
Celosa trigyna	Yewusha berber	Hot pepper, maize, tef, sorghum, soybean, h. bean	Noxious	Predominant from end July
Polygonum nepalense	Yebeg lat	Maize, sorghum, hot pepper	Noxious	Serious from end June to end August

Table 1. Cont'd

Galingsoga parviflora	Ager atfa	All major crops	Noxious	Serious from mid June to early September
Ageratum conizoidus		All major crops	Moderate	Serious after most crops flower
Cloeme monophylla		Maize, sorghum	Moderate	Important in early season
Leucas martinicensis		Maize, soybean	Moderate	
Chenopodium spp.		Maize, tef	Moderate	On tef late in season, On maize early season, in mid season no effect
Erucastrum spp.	Yewisha gomenzer	Sorghum, hot pepper	Minor	seen in early season and then withers
Nicandra physalodes		Maize, sorghum	Minor	
Panicum spp.		Maize	Minor	
Striga hermonthica	Kitgne	Sorghum, maize	Minor	Alarming in Selga and Bambasi areas
Orobanche minor		Ground nut	Minor	Introduced with seed
Cuscuta spp.	Dodder	Noog	Moderate	Expected to be an introduced problem
Rottoboellia cochinchenensis		Sorghum	Minor	Observed at Bambasi 43 and is increasing rapidly

[a] Species identification by Chris Parker, Consultant.

Table 2. Labor requirement and partial budget analysis of different weeding treatments on tef.

Treatment (DAP)	Work-days ha^{-1} 1986	1987	1988	Mean yield	Gross benefit	Cost of weeding	Net benefit	Marginal benefit
15-20	1	18	21.4	13.5	296.4	26.32	270.1	-45.1
35-40	11	18	62.7	30.6	324.4	59.7	264.7	-52.5
55-60	15	16	58.0	29.7	345.8	57.9	287.9	-29.3
80-85	9	14	26.0	16.3	319.8	31.8	288.0	-29.2
15-20 & 35-40	11	15	29.5	18.5	327.0	36.1	290.9	-26.3
35-40 & 55-60	0	0	0	0	317.2	0	317.2	0
55-60 & 80-85	-	14	56.7	35.4	333.5	69.0	264.4	-52.8
15-20, 35-40 & 55-60	57	-	57.0	57.0	351.0	111.5	239.9	-77.4
35-40, 55-60 & 80-85	55	-	-	55.0	345.8	107.3	238.7	-78.7
15-20, 35-40, 55-60 & 80-85	50	-	-	50.0	346.5	97.5	249.0	-68.3
Unweeded check	46	-	-	46.0	338.0	89.7	248.3	-68.9

DAP - days after planting

Table 3. Partial budget analysis of weeding treatments of maize at Assosa.

Weeding treatment (DAP)	Number of weedings	Cost of weeding	Gross benefit	Net benefit	Marginal benefit
No-weeding	0	0	98.1	98.1	0
20-25	1	47.6	450.0	402.4	304.3
40-45	1	87.6	419.6	332.0	233.9
60-65	1	102.8	278.3	175.5	77.4
80-85	1	170.0	135.5	-34.5	-132.6
20-25 and 40-45	2	89.1	671.0	581.9	483.8
60-65 and 80-85	2	150.2	259.4	109.2	11.1
20-25, 40-45 and 60-65	3	126.6	644.7	518.1	420.0
40-45, 60-65 and 80-85	3	170.6	630.7	260.1	162.0
20-25, 40-45, 60-65 and 80-85	4	147.6	662.3	514.7	416.6

Gross benefit = yield (treatment) x price of one quintal maize
Net benefit = gross benefit - cost of weeding
Marginal benefit = net benefit in excess of the weedy check

Table 4. Effect of weeding treatments on plant height, population density and grain yield of maize, Assosa (1986-88).

Weeding treatment (DAP)	Plant height (cm)	Density per plot	Grain yield (q/ha) 1986	1987	1988	Mean	Yield (%) decrease
No weeding	164	22	9.6f	2.6f	1.8d	4.7d	85
20-25	218	38	32.3c	15.7bcd	16.3c	21.4bc	33
40-45	219	37	29.0cd	13.2def	17.8bc	20.0a	37
60-65	173	31	24.1de	12.1def	3.6d	13.3cd	59
80-85	150	27	14.0ef	3.1ef	12.2d	6.4d	80
20-25 and 40-45	233	45	48.9a	25.4ab	21.6abc	32.0a	0
60-65 and 80-85	163	33	27.9de	10.0def	5.1d	14.3cd	61
20-25, 40-45 and 60-65	223	41	37.4bc	26.8a	27.9a	30.7ab	4
40-45, 60-65 and 80-85	206	39	35.9c	12.3def	13.3c	20.5c	36
20-25, 40-45, 60-65 and 80-85	224	43	46.9ab	22.9abc	24.8ab	31.5a	1
Mean	198	36	30.0	14.4	13.4	19.5	
S.E. (±)			3.1	0.4	2.5	3.0	
CV (%)			21.0	45.0	37.0	31.0	

Means followed by the same letter within a column are not significantly different at the 5% level of the DMRT.

Table 5. Effect of weeding treatments on pod yield and yield components of hot pepper, Assosa (1986-1988).

Weeding treatment	Marketable yield				Unmarketable yield				Total	Pods	Pods	No.	
(DATR)	1986	1987	1988	Mean	1986	1987	1988	Mean	yield	no./plt	wt/plt	main br.	% R
15-20	0.7f	0.0d	0.3d	0.4d	1.5	0.1	0.0	0.6	0.9c	5	1.1	6.4	87
35-40	1.9e	0.2d	1.5cd	1.2d	4.7	0.4	0.0	1.7	2.9bc	6	1.9	10.2	60
55-60	4.0cde	0.0d	2.6cd	2.2cd	3.7	0.0	0.1	1.3	3.5bc	5	0.9	8.9	52
80-85	2.5de	0.0d	0.9d	1.1d	1.6	0.1	0.2	0.6	1.7c	4	0.8	8.8	77
15-20 & 35-40	2.9de	2.0ab	1.1cd	2.0cd	4.1	0.6	0.0	1.6	3.6bc	7	1.5	8.9	50
35-40 & 55-60	-	0.5cd	3.2bcd	1.9*	-	0.4	0.1	0.2	3.3*	4	2.0	8.1	45
55-60 & 80-85	4.9bcd	0.1d	2.7bcd	2.6bcd	3.7	0.1	0.1	1.3	3.9bc	6	1.0	6.1	46
15-20, 35-40 & 55-60	6.7abc	1.5abc	4.3abc	4.2abc	4.9	0.5	0.1	1.8	6.0ab	8	1.8	5.8	17
35-40, 55-60 & 80-85	8.1a	0.9bcd	7.6a	5.5a	4.7	0.3	0.2	1.7	7.3a	7	1.5	6.6	0
15-20, 35-40, 55-60 & 80-85	7.7ab	2.2a	6.2ab	5.4ab	4.5	0.9	0.1	1.8	7.2a	6	2.1	7.7	0.7
Unweeded check	0.4*	0*.0	0.1*	0.2*	0.3	0.0	0.0	0.1	0.4*	2	1.0	5.3	94
Mean	4.0	0.7	2.8	2.4	3.4	0.3	0.1	1.2	3.7	6	1.4	7.5	
S.E. (±)	0.9	0.4	1.1	0.9					1.0				
CV (%)	39.0	97.0	75.0	62.0					48.0				

% R : Percent yield reduction [(1-treatment yield/highest yielder)x100]

* were not included in the analysis

- - no data

Means followed by the same letter were not significantly different at the 5% level of the DMRT.

Table 6. Labor requirement and partial budget analysis of weeding treatments, Assosa (1986-1988).

Weeding treatments (DATR)	Work-days/ hectare	Cost of weeding	Marketable yield (q/ha)	2.50 Ethiopian Birr/kg		
				Gross Benefit	Net Benefit	Marginal Benefit
15-20	15.1	29.5	0.35	88	59	21
35-40	58.6	114.3	1.17	293	179	141
55-60	85.9	167.5	2.18	545	378	340
80-85	100.0	195.0	1.08	270	75	37
15-20 & 35-40	36.8	71.8	2.03	508	436	398
35-40 & 55-60	70.3	137.1	1.86	465	328	290
55-60 & 80-85	88.6	172.8	2.85	645	472	434
15-20, 35-40 & 55-60	48.9	95.4	4.17	1043	948	910
35-40, 55-60 & 80-85	86.6	168.9	5.53	1383	1214	1176
15-20, 35-40, 55-60 & 80-85	58.1	113.3	5.37	1343	1230	1192
Unweeded check	0.00	0	0.15	38	38	0

One work-day is eight working hours.
One work-day/ha costs Eth. Birr 1.95.
Gross benefit = Yield of each treatment multiplied by the price of one quintal of hot pepper.
Net benefit = Gross benefit minus cost of weeding.
Marginal Benefit = Net benefit of each treatment in excess of the gross benefit of the Check.

Three to four weedings at three, five, eight and twelve weeks following the transplanting of hot pepper gave the highest yields and marginal benefits. Frequent removal of weeds during the first twelve weeks, therefore, is believed to be advantageous for hot pepper in Assosa and similar areas.

The highest mean yields of sorghum, 30.66, 28.31 and 24.93 q/ha, were obtained from weed free up to 75, and 60 days after planting, respectively (Table 7). On the other hand, the lowest yields, 1.73, 1.89 and 2.06 q/ha, were found from plots un-weeded throughout the season and weed infested plots up to 90 and 75 days after planting in that order. The critical time of weed competition for sorghum was observed to be between the 3rd and the 7th week after planting. Therefore, continuous removal of weeds was observed to be best in achieving a high biological yield.

Herbicide application in maize showed a statistically significant difference in contrast to unweeded plots. Alachlor plus atrazine at the rate of 1.25+1.25 kg a.i./ha gave the highest (29.8 q ha^{-1}) grain yield, whereas the weeded check plot gave 26.16 q ha^{-1} and the unweeded 4.75 q ha^{-1} (Table 8). The highest cost (138 Birr ha^{-1}) of slashing was incurred from 1+1 kg a.i. ha^{-1} atrazine+terbutryn and the lowest (72.23 Birr ha^{-1}) from atrazine+pendimethalin at 1+1.65 kg a.i. ha^{-1}. But the weeded check incurred a cost of 168.34 Birr ha^{-1}. The least controlled weed after herbicide spraying was *Eleusine indica.*

Grain yield differences in sorghum due to herbicide application were not statistically significant. However, sole atrazine 1.75 kg a.i. ha^{-1} was best in weed control and gave the second highest grain yield, 11.4 q ha^{-1} (Table 9). The weeded check plot gave 11.8 q ha^{-1}. The highest phytotoxicity score of 7 and 66.7% general weed control were recorded with 1.25+1.25 kg a.i. ha^{-1} atrazine+terbutryn. As compared to the cost of slashing weeds, the cost was very low when sorghum was sprayed with herbicides. By and large, chemical control of weeds in maize and sorghum was found economical as compared to hand weeding.

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Table 7. Grain yield, cost of hand weeding, yield loss and marginal benefit of sorghum at Assosa.

Treatment	Grain yield (q/ha)	Work-days ha^{-1}	Cost ha^{-1}	Gross benefit	Net benefit	Marginal benefit	Yield		Rank
							Gain	Loss	
15dap ww	5.7	20.3	39.6	142.5	103.0	59.7	229.5	81.4	23
30 + +	13.6	22.5	43.9	339.0	295.1	251.9	683.8	55.8	11
45 + +	22.5	71.4	139.2	561.3	422.8	378.8	1197.7	26.8	6
60 + +	24.9	72.5	141.4	623.3	481.9	438.6	1341.0	18.7	4
75 + +	30.7	101.7	198.3	766.5	568.2	525.0	1672.3	0.0	1
90 + +	22.2	124.2	242.1	555.0	312.9	269.6	1183.2	27.6	7
15 + wf	28.3	141.9	276.8	707.5	431.0	387.7	1536.4	7.7	2
30 + +	20.1	141.4	275.1	502.0	226.9	183.7	1060.7	34.5	9
45 + +	9.6	149.2	290.9	239.5	-51.4	-94.6	453.8	68.8	12
60 + +	2.4	176.1	343.4	61.0	-282.4	-325.7	41.0	92.0	14
75 + +	2.1	186.7	364.0	51.5	-312.5	-355.8	19.1	93.3	15
90 + +	1.9	188.6	367.8	47.3	-320.5	-363.8	9.3	93.8	16
15 & 30 dap wd	14.7	39.4	76.9	361.8	284.8	241.6	736.4	52.8	10
15, 30 & 60 dap wd	22.2	65.3	127.3	554.3	426.0	383.7	1181.5	27.7	8
15, 30, 60 & 90 dap wd	25.1	97.5	190.1	626.3	436.1	392.9	1348.0	18.3	3
wf es	24.1	146.7	286.0	603.0	317.0	273.8	1254.2	21.3	5
uw es	1.7	–	0.0	43.3	43.3	0.0	0.0	94.4	17
Mean	16.0	102.7	200.2	339.1	199.0	–	826.8	–	–

ww - with weed, wf - weed free, wd - weeded, es - entire season, uw - unweeded

Table 8. Effect of herbicide treatments on the performance of maize at Assosa.

Treatment	Dose (a.i. kg/ha)	Effect of chemical (1-9)[a]		General weed score (%)		Yield (q/ha)	Cost of slashing (Birr/ha)
		29dap	38dap	29dap	88dap		
atrazine	1.75	3.00	4.75	90.00	28.75	19.38abcde	114.70
atrazine	2.00	3.00	4.75	90.00	27.50	14.85c-h	114.70
atrazine+metolachlor	0.88+0.88	2.75	4.25	91.25	32.50	17.92b-g	108.34
atrazine+metolachlor	1.00+1.00	2.50	3.50	88.75	41.25	19.22a-f	95.59
atrazine+alachlor	1.00+1.00	2.75	4.00	91.25	37.50	14.68c-e	102.49
atrazine+alachlor	1.25+1.25	2.75	2.25	91.25	43.75	29.80a	81.78
atrazine+pendimethalin	0.75+1.32	3.00	5.00	92.50	27.50	12.96c-m	108.34
atrazine+pendimethalin	1.00+1.65	3.25	4.00	90.00	31.25	23.84abc	72.23
atrazine+terbutryn	1.00+1.00	3.75	6.00	85.00	25.00	14.92c-j	138.08
atrazine+terbutryn	1.25+1.25	2.75	4.75	90.00	31.25	20.71abcd	106.22
metolachlor	1.68	4.00	4.75	81.25	20.00	16.67d-i	108.34
alachlor	1.72	3.00	4.50	90.00	26.25	14.46c-m	82.84
pendimethalin	2.00	4.00	4.50	86.25	20.00	18.38b-f	93.99
terbutryn	4.00	3.25	4.75	86.25	21.25	17.12b-h	127.45
weeded check	–	1.25	1.75	98.00	99.00	26.16ab	168.34
weedy check	–	7.50	7.00	5.00	0.00	4.73m	0
Mean							100.46
SE (±)						3.25	
CV (%)						36.34	

a - 1 is complete kill of weeds and no effect on crop; 9 is no effect on weeds and complete crop kill.

Table 9. Effect of herbicide treatments on the performance of sorghum at Assosa.

Treatment	Dose (a.i. kg/ha)	Effect of chemical (1-9)[a]		General weed score (%)		Yield (q/ha)	Cost of slashing (Birr/ha)
		31dap	90dap	31dap	90dap		
atrazine	1.75	5.25	5.75	73.30	26.70	7.32	114.7
atrazine	2.00	5.75	4.25	73.30	50.00	11.39	114.7
atrazine + metolachlor	0.88+0.88	5.00	6.25	75.00	58.30	5.07	108.3
atrazine + metolachlor	1.00+1.00	5.25	4.25	56.70	41.70	8.78	95.6
atrazine + alachlor	1.00+1.00	5.00	6.75	65.00	55.00	5.71	102.5
atrazine + alachlor	1.25+1.25	6.25	5.25	65.00	50.00	6.49	81.8
atrazine + pendimethalin	0.75+1.32	4.25	5.25	80.00	19.70	7.74	108.3
atrazine + pendimethalin	1.00+1.65	4.75	5.00	70.00	40.00	4.60	72.2
atrazine + terbutryn	1.00+1.00	7.00	6.25	67.70	66.70	4.33	138.1
atrazine + terbutryn	1.25+1.25	3.25	3.75	76.70	46.70	9.20	106.2
metolachlor	1.68	5.75	6.75	71.70	31.70	3.03	108.3
alachlor	1.72	3.75	6.25	75.00	18.30	3.05	82.8
pendimethalin	2.00	5.25	6.50	60.00	16.70	3.62	94.0
terbutryn	4.00	4.50	5.75	56.70	23.50	6.65	127.5
weeded check	--	--		95.00	99.00	11.79	168.3
weedy check	--	--		0.00	0.00	1.16	0.0
Mean				66.26	40.25		101.5
SE (±)						2.25	
CV (%)						70.66	

a - 1 is complete kill of weeds and no effect on crop; 9 is no effect on weeds and complete crop kill.

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