Arem

Editor
Rezene Fessehaie

First Annual Conference of
the Ethiopian Weed Science Society
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Addis Abeba, Ethiopia

Volume I

Ethiopian Weed Science Society

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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.

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Welcome Address

Rezene Fessehaie
President, EWSS

Your Excellency Dr. Awetahegn Alemayehu
Vice-Minister of Agriculture,
Distinguished Guests, and
Fellow EWSS members,

On behalf of the Executive Committee of EWSS and in my own behalf, I am honoured to have the privilege of welcoming you all to the First Annual Conference of the Ethiopian Weed Science Society. It is a pleasure to have with us our guest of honour, His Excellency, Dr. Awetahegn Alemayehu to give an opening address to this annual conference.

We are also privileged to have several distinguished guests from various ministries and representatives of professional societies, and we would like to thank them for their kind willingness and interest to actively participate in our conference.

Distinguished Conference Participants,

Last year on the same day the 10th Anniversary Conference of the Ethiopian Weed Science Committee (EWSC) was held in this conference hall. This event was a remarkable occasion in the history of the weed science discipline in Ethiopia, as it is the first time where members of EWSC have come together to inaugurate the formation of the Ethiopian Weed Science Society (EWSS).

A special feature of the past conference was the recognition of selected individuals and organizations for their contribution to the development of weed science discipline in the country in general and the EWSC in particular. During the occasion four outstanding members were honoured with the EWSC Fellowship Award and 24 more individuals and 10 organizations received certificates for outstanding contribution. During the inaugural session, a new constitution with clearly outlined objectives, policies and liabilities was discussed in detail and approved by the General Assembly.

Dear Participants,

Since the establishment of EWSS, the Executive Committee members of the Society have devoted a great deal of their time to upgrade the status and standard of the Society. The EC had held 6 regular and more than 4 urgent meetings and carried out several duties to strengthen the Society in membership, finance and publications.

This conference is sponsored by the Institute of Agricultural Research (IAR), the Ethiopian Science and Technology Commission (ESTC) and Ciba Geigy. On behalf of the Society, I would like to express my sincere appreciation and gratitude for their support.

Honourable Guests,
Dear EWSS members,

Today and tomorrow research papers exploring the different areas of weed science will be presented and discussed. Topics of special interest include: weed science literature, plant health clinics and herbicide regulations.

With this brief remarks, may I respectfully invite, His Excellency, Dr. Awetahegn Alemayehu to officially open the First Annual Conference of EWSS.

Thank You!

Opening Address

His Excellency, Dr. Awetahegn Alemayehu
Vice-Minister of Agriculture

Mr. Chairman,
Distinguished Guests,
Conference Participants,

I would first of all like to express by deep-felt pleasure for being invited to address the First Annual Conference of the Ethiopian Weed Science Society (EWSS). I thank the organizing committee for giving me this unique privilege.

I would like also to congratulate the general membership of EWSS, for your success in forming a Weed Science Society and in organizing this conference of high importance.

It is accepted that we must explore all possibilities of improving the recurrent food deficit the nation has been experiencing for the past two decades. Part of this problem appears to be the result of incompatibility of the traditional agricultural practices and the unstable meteorological phenomena. Despite the long history and tradition of agriculture in this country, our agricultural production systems are quite unproductive, particularly in the small scale peasant sector which accounts for over 90% of the national agricultural produce. This sector is characterized by low cost inputs such as seeds, fertilizers and crop protection schemes. Needless to say, these low cost and largely traditional agricultural inputs and husbandry practices are not the most effective means for raising agricultural productivity. It can be safely stated these low inputs and traditional practices are largely responsible for the low yield per hectare of all crops by small scale farmers.

Mr. Chairman,
Conference Participants,

In my address to you this morning, I would like to focus on the severity of weed problems in the hope that you may come up with some practical and workable recommendations useful in reducing crop losses caused by weeds. This is important because any research finding-be it weed, crop disease or insect control, crop variety improvement, or farm tools innovations, etc., it must be prepared in the most useable and practical form and be made available to the farmers locally at the right time and in the most affordable price. Before I go into the matter of weed problems and improvement measures, however, please allow me to touch upon and make some brief comments on one or two important points.

Dear Participants,

This conference is being held at the most opportune time when peace has been established in the country after along struggle and urgent development is the need of the hour to achieve democratic reforms. Rapid agricultural development would enhance the development of other sectors also.

Here, I need hardly remind you the importance of agriculture to our national economy. It is quite obvious to all of you. It is, in short, the very foundation upon which the whole socio-economic structure of the nation is build. The fact that this foundation is weak and shaky has led to the fragile nature of our entire national economy. Thus, in order to develop a strong and viable national economy, we have no other choice but to spur the development of our agricultural sector. We desperately need to increase our agricultural production in order to be able to feed ourselves, to provide adequate raw materials for processing industries, to supply exportable products for earning foreign exchange, to create ample employment opportunities and to spark development in the rural areas. This increased agricultural production, however, comes from new techniques or methods and materials put into practice on farms. Experience has proved time and again that it is simple not possible to get much increase in production by using the same soil in the same old ways.

This means that the technologies of agriculture must be constantly changing. When they stop changing, agriculture becomes stagnant. Production stop increasing and it may even decline due to decreasing soil fertility or increasing damage by multiplying weeds, insects and diseases.

The irony is that, Mr. Chairman and Dear participants, many experts believe that Ethiopia could be come the breadbasket of Africa if its agricultural potentials were fully developed.

Changes in technologies can come about only as a result of research. The question one must ask then is, 'what kind of technology and extension system should be adopted in order to enhance our agricultural production? Here, we must remind ourselves that the availability of appropriate technology and an extension system or a combination of the two and other factors would not by themselves guarantee more agricultural production. In this process the farmer must be consulted. The desires and complaints voiced by farmers should be carefully considered and plans drawn up in full knowledge of what the judgements of farmers are as to what they need inorder to move ahead. The results of research obtained by our national research institutions and other appropriate technologies adopted in line with our objective conditions must be incorporated in a very simple form as one extension package and passed on to farmers through the extension agents.

Dear Participants,

Historically, weed problems in Ethiopia have received less attention than any other crop pests and as compared to other crop protection disciplines, weed science has the lowest trained specialists. Weeds cause tremendous amount of crop losses every year, but such losses are not usually as apparent as in the case of insects and pathogens. Weed science has evolved as a separate discipline only relatively recently, and it can be argue that in many places it is still not recognized as such. Fortunately and thanks to some highly dedicated specialists, at present, there exists very intensive research activities in this field in some of our national research institutions, and research on weed problems has come to be appreciated as a scientific discipline of its own. Inspite of its firmly established role in research, however, weed science is not well represented in vocational training. The main reason for this paradox is that a young discipline need time to be accepted by related disciplines before it is finally integrated into the more or less rigid structure of traditional educational systems.

Mr. Chairman,

It is gratifying for me to see that many of the prominent research scientists, agricultural educators and agricultural development workers are assembled in this conference hall. It is my sincere hope that this conference will be able to discuss relevant issues on how to improve the transfer of already available weed management technologies to farmers on the one hand, and also consider and give direction to future weed science research activities in the country on the other.

Encouraging and supporting professional societies like the Ethiopian Weed Science Society is a policy the Ministry of Agriculture strongly endorses. We have keenly observed the development attained by the ex-Ethiopian Weed Science Committee in the past 10 years to lay the foundation in establishing the Ethiopian Weed Science Society, and we are encouraged by the progress it has made. The need for such professional societies to serve as a focus for spearheading research and development in this country is very great.

Finally, Mr. Chairman, I wish the 1st Annual Conference of the Ethiopian Weed Science Society every success.

It is now my pleasure and privilege to declare the 1st Annual Conference of the Ethiopian Weed Science Society open.

Thank You.!

Closing Remarks

Tesfaye Zegeye
Deputy General Manager for Administration,
Institute of Agricultural Research

Mr. Chairman,
Distinguished Members of
the Ethiopian Weed Science Society,
Ladies and Gentlemen,

I am very greatly honoured to have been invited to get this opportunity of making the closing remarks on this historic occasion of the First Annual Conference of the Ethiopian Weed Science Society (EWSS).

It is evident to us that no activity is contributing more to our economy than agriculture in Ethiopia today. It plays a pivotal role in providing food, shelter, clothing and foreign exchange earnings. It is, in short, the very foundation upon which the whole socio-economic structure of the nation is built. Thus, in order to develop a strong and viable national economy, we have no other choice but to spur the development of our agricultural sector.

All these developments require the deep involvement of our crop scientists and high commitments on the part of the government. The challenges are immense and the opportunities are far reaching. This is where the role of the professional Societies like EWSS becomes crucial.

Mr. Chairman,
Invited Guests,
Dear EWSS Members,

I think I have in a nutshell said what I intended to. The first annual conference of EWSS has been a very encouraging start with regard to number of participants and quality of presentations. The organizing committee has carried out a commendable job to make the conference a success. I am sure, all participants of this conference will remember members of the organizing committee for undertaking the difficult task of bringing this professional society into a success.

Finally, on behalf of the Institute of Agricultural Research and on my own behalf I assure you that my Institute will be at your side and will try to do all its best in assisting and encouraging your society to realize its most cherished objectives and goals.

With these few remarks, I have the pleasure in declaring the First Annual Conference of EWSS officially closed.

Thank You!

Scope and content of weed science publications

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Abstract

An examination of the limited number of publications before the last two decades, wholly or partially devoted to weeds and weed control practices reveals that the efforts made were insignificant. Since the early 1980s, however, a considerable emphasis on the identification, ecology, impact on crops, herbicide evaluation, and tillage practices has been made. It is estimated that over fourty items of weed science - related publications are published or presented in annual meetings in the country. Most of the publications are the results of conferences, workshops and symposia. Recently, the number of graduate students working on weeds for their degrees is increasing. Their theses and dissertations are contributing to the build up of information capability in the science of weeds and their management. This study attempts to identify areas of focus or preferences of weed scientists for synthesizing their papers.

Introduction

Many scientists agree that weed science, as a multidisciplinary entity can be entitled to a place among the older agricultural sciences, however, it has attained its profile in Ethiopia only in the last couple of decades. Though a course on weed science has been given in different forms and contents to students of higher education in agricultural science *ab initio* agricultural education in the 1940s.

As can be seen from the objectives of the Ethiopian Weed Science Society (EWSS) and the efforts of weed scientists, dissemination of information is one of their integral functions. As in the case with any scientific discipline, agricultural scientists and development officers depend mainly on bibliographies for preparing papers and for current awareness on what is new in their fields of specialty. Knowledge of this is not meaningful without a prior understanding of the scope, nature and relevance of the major types of publications.

An examination of the limited number of publications before the last two decades, wholly or partially devoted to weeds and weed control practices reveals that the efforts made were insignificant. Since the early 1980s, however, a considerable emphasis on the identification, ecology, impact on crops, herbicide evaluation, and tillage practices has been made.

The range of publications on weed science, which is of potential interest to scientists, educators, and development agents and the farming community is extremely wide, since the discipline is closely related to the various crop production techniques. In many respects weed science may be regarded as a technology, i.e., an application of the basic science, especially of the biological sciences and chemistry. Moreover, its scope includes socio-economic aspects and trans-border transactions of seeds. Weed science also encompasses other technologies like farm machinery. Thus, weed scientists can take advantage of the versatility of profession.

Even though there has been no classification of weed science publications, a wide range of information sources can be cited some what categorically, the major types are listed below:

A. Fugitive
- newsletters
- press releases
- weed incidence reports
- posters

B. Non-scientific
- quarantine rules and regulations
- herbicide specifications
- advisory publications

C. Scientific
- theses and dissertations
- technical manuals
- research reports
- books
- working papers
- journal articles
- conference/workshop proceedings
- book chapters
- consultancy and terminal reports

As compared to the other agricultural specialities the contribution of weed science publications is low. It accounts for not more than 3% to the total agricultural publications. Although the percentage contribution appears low, it is one of the best documented disciplines in the country. The form weed R&D results are documented obviously is a reflection of the quantitative as well as qualitative factors revolving around weed scientists and development officers.

Despite the importance of weed science publications, much of them provide next-to-nothing to the grass-root information users. Future endeavors should, therefore, be geared towards the practical aspects of weed management. Moreover, improved methods to users of weed science publications, who wish to keep informed of the available publications and want to obtain those relevant to their interests should be facilitated using modern information management tools.

The majority of the publications, particularly those in old days, are not well covered by secondary bibliographic services and are available only in limited information resources. Recently, however, the Information Services of the Institute of Agricultural Research (IAR) has started inputing locally produced agricultural publications to International databases, mainly to International Information System for the Agricultural Sciences and Technology (AGRIS), and a local database has been established in IAR to include all local agricultural publications. This effort requires the collaboration of scientists, educators and development agents and their respective organizations in depositing a copy of their publications in IAR and help build the accessibility and further use the publications via networking facilities.

The source materials for this study were collections from IAR library. Weed scientists and agronomists have also been consulted on clarification of some concepts related to their experiences on weed science publications both as readers and authors.

The central idea of this study is an overview of the notion of publishing practices by weed scientists and development agents i.e. the combination of attitudes and practices in relation to scientific and technical communication, which is a vital part of their responsibility.

Categories of Publications

The dissemination of results on the major components of research on weeds has been through the proceedings of the many national, regional, international and societal conferences and symposia, without which weed science would not have gained the recognized status it is enjoying at present. Much is owed to the good will and energy of those who paved the way to perpetuate these meetings subsequently. It should also be noted that, in many cases, information from books and journals published elsewhere is extensively incorporated in papers presented in conferences and subsequently published in proceedings by weed scientists and their affiliated colleagues.

The common feature of weed science publications categorized as scientific is that they report the results of either an original research or observations. It is estimated that over fourty items of weed science-related publications are published or presented in a meeting annually in the country. Most of the publications are the results of conferences, workshops and symposia. Recently, the number of graduate students working on weeds for their degrees is increasing. Their theses and dissertations are contributing to the buildup of information capability in the science of weeds and their management. This study attempts to identify areas of focus or preferences of weed scientists for synthesizing their papers. Major areas are often identified as the common foci for weed researchers and extension agents to publish or present a paper in a meeting. As observed from available sources the relative important of the areas is estimated as follows:

- Herbicide evaluation 28%
- Cultural control of weeds 22%
- Survey of weed flora 14%
- Crop weed competition 11%
- Weed biology 4%
- Combinations of various aspects 21%

Fugitive Publications

The position of fugitive publications represents their profile trend. Their number and quality is low as newly emerging communication functions only 1%. At present, EWSS has started issuing a newsletter. Very few press releases and weed incidence reports are available. Poster sessions have become an important addition to EWSS meetings. Posters are gaining much more importance than ever before as visual aids in all walks of life or as a trend in the approach to reaching the grass-roots. In all possible ways, authorities of fugitive publications need to be selective on the proper kind of medium of presenting their results, observations or experiences that is appropriate and beneficial to their audience. Authors also must be aware of the general as well as specialized media to identify the materials relevant to a topic.

In the rapidly developing field of R & D, fugitive publications can play a limited role as an initial medium for reporting results of research or observation. They may present a consolidated knowledge on a particular topic, for their primary content may include results or experiences whose previous publication is scattered in various publications and in reports that are left as grey literature.

Many reasons can be cited for the existence of such publications. As to our experience, the specialized nature of weed science, economic considerations and existing information technology and management options are of primary importance. Other reasons rarely cited are the importance of speed or preference of the author and users in their output.

Non-scientific Publications

This classification can raise conflicting ideas on the categories of publications. But when the information contents are critically analyzed, almost or all are enduring advisory and reference services. For instance, *Guidelines for Herbicides Testing and Recommendations in Ethiopia, Technical Manual No. 1* (Stroud et al. 1992) and *Weed Quarantine and Noxious Weed Activities, Technical Manual No.2* (Parker et al. 1992) are typical. A glance at these publications, shows that the publications help inquirers obtain information on the aspects of herbicide evaluation, weed quarantine activities and a few other related interests. The contents of these manuals largely give adequate information and enable to draw some inferences about the level of interests on weed control practices and the principles pursued in the country.

Non-scientific weed science publications account nearly 3% of the total publications. For various reasons, this category of publications is becoming an important media for the dissemination of weed management rules and regulations and herbicide specifications or recommendations.

Scientific Publications

Scientific publications, the major media, account for about 96 percent of the total weed science publications in the country. The distribution of these publication is estimated as follows.

o Conference proceedings	78.0%
o Progress reports	12.6%
o Theses and dissertations	3.8%
o Technical manuals	1.4%
o Journal articles	1.2%
o Books	1.0%
o Consultancy and terminal reports	1.0%
o Research reports	0.5%
o Working papers	0.5%

Turning from the general to specific types of publications, one can easily find works that review past activities and provide suggestions for future trusts. The progress reports of IAR, CADU/ARDU and Alemaya College of Agriculture can be considered as the formative reference sources for weed science in general and weed control in particular. Articles in proceedings also occupy a large profile in this respect. Papers in the National Crop Improvement Conference (NCIC) proceedings, even though they are not critical in their contents, represent a scientific approach to the strength of weed science publications. Some of these papers are still valuable. The appearance of refined and inclusive publications was first and foremost seen in the *Review of Crop Protection Research In Ethiopia* (Tsedeke Abate (ed.) 1985). Subsequent proceedings of the Ethiopian Weed Science Committee (EWSC), very specific to Weed Science, began to appear since the mid 1980s. These proceedings were edited by Parker, Rezene and Ahmed Sherif in different editorial capacity. Papers in these proceedings were drawn from workers affiliated to different institutions, development organizations and private companies. Most of the papers cover general aspects and a few are specific to weed problems. Of the specific approaches, the most important and useful end-products of weed science research, like identification of noxious weeds, crop/weed competition and herbicide evaluations, are well documented in the above proceedings. To date, there is a continuing effort in documenting such relevant information for the various agro-ecologies of the country.

Another important aspect observed in most of these proceedings is either the lack of less attention given to the guiding influence of the editor to lead some authors to the central theme in an adequately balanced manner. Identifying appropriate authors, who have demonstrated expertise in their specialty, is one of the essential tasks of the editor or the editorial board.

In the formative period of weed science research in Ethiopia, a survey report prepared by Chris Parker entitled: *Weeds in Ethiopia, Conclusions from a 7-week Survey (1970)* is still serving as a hot literature for researchers and development agents alike.

It is interesting to note that weed-related journal articles are very few in local journals, particularly in the *Ethiopian Journal of Agricultural Sciences (EJAS)* in 1979, only 3 articles have been published on Weed Science, which accounts for only 2.52% of the total articles published so far. A comparison of related disciplines shows that, 9(7.56%) in agronomy and 31(26.05%) crop protection articles are available in EJAS.

An essential aid to identifying weeds, and an important aspect in Weed Science in A *Weed Identification Guide for Ethiopia* (Ann Stroud and Chris Parker 1989). Some weed species are matched against the illustrations in this guideline.

As in many other scientific papers, lingering jargons are not that common in most weed science publications; they rarely come quite naturally. There cannot be an argumentative rationale behind this other than the contents of these papers have perhaps applied kind of or development information. Thus, this approach is helpful for a clear and simple transmission of ideas.

The role of agronomists, agricultural economists and biologists in producing scientific papers on weed-related topics is collosal to note. Hitherto, their role occupies a 43% of the total publications available on weeds.

Attitudes and Trends

Quotation Choices

Quotations are usually short in weed science publications. On the average 1-2 sentences are quoted by weed scientists from other works. Longer statements or sentences are much preferred by scientists writing on weed survey results and herbicide evaluations than on other areas of foci identified in this study. Papers on crop loss assessment and weed biology studies showed briefer quotations. Despite their quotation preferences, many authors tend to give less attention to decide on which passage they want to quote and which tables or illustrations they want to reproduce from other sources. This increases the work load on the editors and prolongs the gestation period for the final publication of the manuscript and thereby broadens the chance for rejection.

Reference Sources

Although no quantitative assessment of information has not been made, in the most cases progress reports, conference proceedings, books and technical manuals — mainly prepared by herbicide manufactures and dealers — are found to be the most preferred sources of reference. Journals, theses and dissertations are quoted in relatively lesser frequency than the above-mentioned sources. Unpublished sources also occupy a substantial proportion. It is worth mentioning that the rate of quotations from local references constitutes a larger proportion, reaching up to 34% from the total source materials. In a sample of randomly selected 14 articles published in the last three issues of EWSC proceedings, quotations from the preceding EWSC proceedings themselves showed that about 0.53% of the articles published each year were frequently quoted. One of the fascinating features of weed science publications is that references to tables and figures from other works are properly listed as a note under each citation and at the references list section. However, in the references list, there is a wide difference in style among authors in terms of punctuation, typography and the arrangement of the various sections of each reference entry.

Authors and Authorship

About 80% of all weed science publications are written by single authors, and 13% by two authors, while 7% are by more than three authors. Multiauthorship is observed on papers from research institutions than from development organizations and private companies. Review papers are often written by more than one author than the other publications.

Editorial Status

The general editorial policies and practices of the then EWSC and the present EWSS do not seem to have an independent board. If at times such an independent board was available, its collective responsibilities would have been hardly noticed on their information products. This is not unique to EWSS, it also applies to some other professional societies. The responsibility for maintaining the editorial standard and advising on editorial policy should be delegated to an editor-in-chief, an editorial board and an editor. Volunteering in such tasks might serve the purpose of lifting up the standard of weed science publications, though may not fill in open spaces for editors or editorial board. This is an essential aspect of scientific writing and is not a difficult requirement to meet.

Therefore, members of EWSS and the Executive Committee are supposed to let the pendulum swing in the opposite direction.

Conclusion

In information dissemination today, a professional society must have a deep insight into the grass roots audience and the capability to react quickly. That is one of the reasons why a society should maintain its existence. Access to and reliance on correct, timely, complete, and first-hand information is very possible through a society. Moreover, unnecessary duplication of concepts and recommendations to be presented in the conference will be avoided. This undoubtedly requires a dynamic knowledge base of weed information system.

Publications are by and large the ultimate key to EWSS's operation and capacity-building efforts. EWSS is well established. But it should be more organized to satisfy the dispersed need of the farmers of Ethiopia. Therefore, EWSS should gain control over its information functions. Simple and precise information should be transferred to the low literacy. Development of a tailored information in weed control and management and a distribution scheme to reach the publication to the farmer should be given priority, since farmers do not go to a book store or a library.

Weed control research: Indian experience

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Abstract

Of the total annual loss of agricultural produce by various pests in India, it is estimated that weeds account for 45%, insects 30%, diseases 20% and other pests 5%. The earliest attempts, in most of the Universities and institutions, weed research was mainly limited to herbicide screening and selection with very little attention to other areas like herbicide physiology, herbicide residue in plant and soil, integrated weed management, herbicide application technology and weed biology. The Indian Council of Agricultural Research (ICAR) recognized the need for strengthening weed research in India by financing and setting up an All India Coordinated Research Program on Weed Control (AICRPWC) in collaboration with the US Department of Agriculture in 1978. This program was started at 7 locations (5 state universities and 2 institutions). The network of centers was reviewed and enlarged in 1981 to include 7 more agricultural univeristies/institutions. In this paper brief review of past weed control research experience in India is presented.

Introduction

Weed science is a miracle which has revolutionized world agriculture through the concept of chemical weed control ever since the development of 2,4-D in early 1940s. The emense benefits offered by the herbicide technology have been almost fully harnessed by the developed countries of the world, while its impact on the agriculture of the developing countries has been only marginal. Although 2,4-D was tested in India as early as 1946, but it has been used on commercial scale only in 1960s onward with the introduction of high yielding varieties of wheat, rice and maize.

There is no reliable study of worldwide damage due to weeds but it has been widely known that weeds cause more losses than any other category of agricultural pests like insects, diseases, nematodes and rodents etc. Of the total annual loss of agricultural produce by various pests in India, it is estimated that weeds account for 45%, insects 30%, diseases 20% and other pests 5% (3).

The loss of food in the world in the year 1975, due to weeds, was estimated at 287.5 million tons or 11.5% of the total food production. Depending upon the degree of competition, weeds reduce crop yields by 10 to 15%. In other words the farm production can be increased by 10 to 15% if the weeds are controlled effectively.

The role of weed research in India

Taking a conservative figure of 10% and annual production of 170 million tons per year in India, the loss due to weeds comes to a staggering figure of 17 million tons of food production per annum. Thus, the annual gross agricultural income of India can be increased by more than 40 billion Rupees or 1.3 billion US dollars by effective weed control alone. This figure will keep on rising with an increase in food production and price of food items.

The crop yield loss due to weeds is highest in the tropics. For example, a study conducted in 5 Asian countries showed that proper weed control increases the yield of rice by 45%. In extreme conditions, weed control may triple the yield of rice.

Heavy infestation of perennial weeds could make land unsuitable for cultivation resulting in loss of its monetary value. Thousands of hectares of cultivable land in rice growing areas of India has been abandoned due to severe infestation of *Cyperus rotundus* and other perennial weeds. In Ethiopia the same thing is true for Fogera plains in Gonder.

Weed management is as old as agriculture itself. But the earliest attempt in India to control weeds by herbicides was made in 1937 for controlling *Carthamus oxycantha* in Punjab by using sodium arsenite. 2,4-D was first tested in 1946. Since then a number of herbicides have been imported and tested for their effectiveness in controlling various weed species. In 1952, the Indian Council of Agricultural Research (ICAR) initiated projects for testing the field performance of herbicides in rice, wheat and sugarcane on coordinated basis in several states in India. But the progress was limited due to lack of trained manpower.

With the establishment of state agricultural universities in 1960s, the weed control programs were, for the first time, manned by full time weed scientists. In addition some of the agricultural chemical companies like Alkali and Chemical Corporation of India, Ciba-Geigy (India), ICI, May and Baker etc, also have well managed herbicide research and development programs.

In most of the universities and institutions weed research is mainly limited to herbicide screening and selection with very little attention to other areas like herbicide physiology, herbicide residue in plant and soil, integrated weed management, herbicide application technology and weed biology.

ICAR recognized the need for strengthening weed research in India by financing and setting up an All India Coordinated Research Program on Weed Control (AICRPWC) in collaboration with the U.S. Department of Agriculture in 1978. This program was started at 7 locations (5 state universities and 2 institutions). The network of centers was reviewed and enlarged in 1981 to include 7 more agricultural universities/institutions. As a result the following weeds were considered most important in India:

1. Winter season(November to April)

- *Chenopodium* spp.
- *Phalaris minor*

- *Avena fatua*
- *Cirsium arvense*
- *Anagalis arvensis*

2. Rainy season(June to November)
- *Amaranthus* spp.
- *Celosia argentia*
- *Convolvulus arvensis*
- *Phyllanthus* spp.
- *Echinochloa* spp.- mainly in rice.

3. Perennial
- *Cyperus rotundus*
- *Cynodon dactylon*
- *Saccharum spontaneum*
- *Sorghum halepense*

4. Aquatic:- Water hyacinth - *Eichhornia crassipes*

5. Waste lands - *Parthenium hysterophorus*
- *Lantana camara*

These weeds are considered as major weeds and the efforts are mainly directed towards their control. In addition some weeds may pose serious problems in some specific cases. For instance, *Orobanche* is a major weed only in tobacco growing areas.

Important weed control measures

Still various techniques of weed control are adopted by farmers to control weeds in various crops. First let us discuss the common weed control practices followed by the farmers. Later we will discuss the recommended weed control practices for various crops.

Mechanical methods

Mechanical or physical methods of weed control are being employed ever since the cultivation of crop plants has begun. Various tillage-primary and secondary-operations are followed for preparation of proper seedbed and removal of weeds from the standing crops. The choice of tillage operation depends mainly on the type of weeds and economic considerations. The mechanical methods of weed control include tillage, hand weeding, digging, hoeing, sickling, mowing, burning, flooding etc.

Tillage: Tillage operations are done primarily to prepare proper seedbed for planting a crop. The important implements used for this purpose are plough, harrow and cultivator. Plough not only removes weeds from the soil, it also buries them in the soil. Even if some of the weeds are not removed or buried they may be pruned and injured to weaken their competitive ability. Sometimes cultivators are also used for interculture operations to control weeds. The concepts of zero or minimal tillage are being evaluated to examine the importance and necessity of tillage operations as means of weed control which can otherwise be controlled by herbicides. But still herbicides have not been established as substitute to tillage.

Hand weeding: Hand weeding is the oldest and still most common method of weed control. It is the removal of weeds by hands or small implement called *Khurpi*. Pulling of weeds is common in sandy and light soils but in heavy or compact soils, *khurpi* can remove weeds and at the same time loosen the soil for enhanced aeration. The weeds with deep root system are usually not removed by this method as the roots are left behind. But this method is very effective to control shallow rooted annual weeds and provides timely relief for crop plants to grow and suppress the weeds at later stages. Usually one or two hand weedings are enough to control weeds effectively in any crop.

Hoeing: Different types of hoes have been the most common implement to control weeds for centuries. Hoeing is still very effective and economical method of weed control. It is very effective to control annual weeds with shallow root system. Even for perennials the top portion is removed to avoid competition at the critical time of crop growth.

Digging: Digging of weeds is very effective in controlling perennial weeds as it uproots the whole plant and results in removal of all the plant parts which may regenerate through vegetative propagation. It is a labor intensive operation and hence applied only under specific problem situations to control deep rooted weeds where other methods are not effective.

Sickling and mowing: Sickle is a very effective and handy tool to remove weeds above the soil surface to give temporary relief to the crop or to prevent seed production by the weeds. It is more effective where hand pulling is not feasible due to heavy or compact soil conditions. Continuous sickling may starve underground weed plant parts and lead to effective control of perennial weeds also.

Mowing is a machine operated process to remove weeds in lawns or along road sides in non-cropped areas. This method does not disturb soil and hence is suitable to control weeds in slopy areas vulnerable to soil erosion.

Burning: It is the most economical method of getting rid of weeds, crop residue, weed seeds and propagating plant parts. But it also burns the organic matter in the soil which is useful for soil fertility and other soil properties. In India burning is a common practice after harvesting of sugarcane crop; where burning is practiced to eliminate weeds, crop residue and diseases and pests before regeneration of ratoon crop of sugarcane.

Flooding: Continuous flooding is an effective method of weed control in puddled rice fields. Most of the weed species are controlled if 5-15 cm deep water is maintained for 3-4 weeks at the critical time of weed crop competition. Some weeds need total sub-emergence for long periods for total control while some weeds grow well even under flooded conditions. So flooding can be followed as a means of weed control for specific weeds like broadleaved annual species.

Stale seedbed method: It has been found effective for control of *Phalaris* and wild oat in wheat crop. To adopt this method the seedbed is prepared about 15-20 days before actual sowing time and left unsown for weeds to grow. The first flush of weeds including *Phalaris* and wild oat emerges in 10-15 days period. Then the seedbed is prepared afresh and all the emerged weeds are controlled in the process. This practice has been recommended to the farmers in weed infested areas of wheat cultivation.

Cultural methods

Some cultural methods are followed to prevent introduction, spread and multiplication of weed species. Under intensive cropping system it is essential to adopt adequate preventive measures for weed infestation. Some of the preventive measures followed in India are discussed here.

Crop rotation: Certain crops encourage the infestation of specific weeds and such crops should be rotated. Rice-wheat rotation is conducive for spread and infestation of grassy weeds like *Phalaris* and wild oat. It is, therefore, recommended that in problem areas this rotation should not be followed on continuous basis. Cultivation of crops like pulses in wheat season can help in identification and effective control of grassy weeds. Similarly sugarcane crop encourages weeds like *Cyperus* and should not be grown on infested lands.

Crop competition: Some crops grow very fast and are better competitor with weeds than others. Such crops like sun-hemp and sesbania should be grown to smother weeds and prevent their seed setting. Also some fodder crops with enhanced plant population may smother weed growth effectively.

Mulching: Mulching by crop residue or other materials like sawdust smothers weed growth by preventing sunlight from photosynthetic portions and inhibiting over all growth. Mulching is very effective for controlling most of the annual weeds. It also helps crop growth by preserving moisture and thus makes the crop better competitor to smother weeds.

Clean cultivation: It involves using weed free crop seeds and prevention of seed production by weeds. For this purpose certified seeds should be used for crops and frequent weeding should be done to prevent growth of weeds. Ultimately seed production of weeds is to be prevented by cutting, mowing or killing the weeds before reproductive phase sets in.

Chemical methods

Various chemicals have been used to control weeds since the beginning of this century.

Bordeaux mixture was for the first time used as herbicide at the turn of the century. They various copper salts were used to control broadleaf weeds in cereals. There was very little progress in the use of chemicals for weed control in the first 3 decades. The concept of systemic control of weeds through absorption of chemicals by roots and top portions of the plant and translocation in plant body got boost with introduction of nitrophenols in 1935. The discovery of 2,4-D in early 1940s has, however, revolutionized the chemical method of weed control. In 1941, 2,4-D was synthesized and used as fungicide and insecticide by Pokorny. In 1942 Zimmerman and Hitchcock tested 2,4-D as growth regulator. Morth and Mitchell used 2,4-D as herbicide for the first time in 1944 in lawns and Hammer and Turkey used it in field weed control in U.S.A. The demonstration of herbicide properties of 2,4-D as herbicide was then started in 1952 on wheat, rice and sugarcane crops on all India basis. Today there are over 250 organic chemicals being used as herbicides under very specific conditions for selective and effective method of weed control.

Biological methods

Biological method of weed control is accomplished by direct or indirect action of organisms such as parasites, predators and pathogens. Crop competition and smothering effect is also considered as biological method of weed control which has been discussed under cultural methods. Here the control of weeds by insects and plant pathogens will be discussed.

Weed control by insects: The first attempts to control weeds using insects have been made on *Lantana camara* in various countries including India, Australia, Fiji and Hawaii. The effective insects to control *Lantana camara* were i/ larvae of *Crocidosema lantana*, (tortricid moth), ii/ larvae of Agromyza lantanae, (seed fly) and iii/ larvae of *Thacla echion* and *Thecla bazochi* (lycaenid butterflies). *Opuntia* spp. is another weed which has been controlled by insects in India and Australia. In india *Opuntia* has been controlled by cochinial insects: *Actylopius indicus* and *Dactylopius tomentosus*. Other weeds that have been controlled by insects to a varied degree include *Hypericum perforatum*, *Cuscuta* spp. *Eupatorium adenophorum* and *Clidemia hirta*. Aquatic weeds have also been controlled by herbivorous fish in ditches. A member of the sunfish family *Tilapia mossiambica* destroys the roots of aquatic weeds and controls their growth by eating the vegetative parts.

Weed control by plant pathogens: Recently plant pathogens have become a good biological agent in controlling problematic weeds. The fungi *Alternaria macrospora* and *Puccinia heterospora* have been found to be epiphytotic on spurred anoda in U.S.A. These pathogens cause significant reduction in plant height, dry weight and seeds and pods per plant.

Biological control of weeds in India

The history of biological control of weeds in India goes back to mid-nineteenth century when *Opuntia vulgaris* was controlled in central and northern parts of India by the Cochinial mealy bug (*Dactylopius indicus*) obtained from Brazil. This bug could not control *Opuntia dellenii* found in South India. Another bug from Srilanka was, however, effective to control *Opuntia dellenii* (2). The lace bug *Teleonemia scrupulosa*, imported from Australia in 1940s proved to be very effective to control *Lantana camara*. The Mexican gall fly *(Procecidochares utilis*) imported from New Zealand in 1963 was released in high elevation areas in north as well as south Indian hills. This insect was very effective in controlling an important broadleaved weed *Eupatorium adenophorum* (1).

Gall forming weevil *(Smicronyx albovariegatus)* produces galls on the roots, stem and branches of *Striga* spp. and the larvae of the Noctuid, *Eulocastra argentisparsa* feed on ripening seeds in fruits of witchweed. Similarly, work is continuing on control of *Cyperus rotundus* by a rhizome and stem boring weevil and the tortricid stem borers, and *Orobanche cernua* by the fly *Phytomyza* which has been used successfully in cabbage, sunflower and tomato. It could not be used on tobacco due to its nicotine content. Recently the larvae of *Diacrisia obliqua* has been found to feed on *Parthenium hysterophorus*, an abnoxious weed (5). Since *Parthenium* is a problematic weed in non-cultivated lands in India, an intensive investigation is required for its control by biological means specific to this species.

Biological weed control offers a great potential for control of some weeds. Though it may never be a solution for control of every weed it can only supplement other weed control methods under certain specific conditions.

Recommendation for weed control in crops

On the basis of the investigations carried out on individual crops the recommendations have been made for successful cultivation of each crop. In the era of Green Revolution and intensive cropping systems, the use of herbicides has become an essential part of weed control methods. The farmer always uses his manual labor for hand weeding or hoeing as far as possible and the recommendations of one or two hand weedings are still valid for most of the crops. In spite of that the farmer is unable to apply one or two hand weeding for the whole area. It is also not possible to identify and remove some of the weeds similar in appearance to the crops like *Phalaris* spp. and wild oat in wheat. Specific herbicides have been tested for such weeds and recommendations are now available. Some of the recommendations for controlling weeds through herbicides in important crops are presented here.

Wheat

Depending upon the type of weed population the following recommendations are made for controlling weeds in wheat (4).

- For controlling broadleaf weeds: 2,4-D at 0.5 kg a.i. ha^{-1}, applied at 30-35 days after sowing.

- For controlling *Phalaris minor*: Methabenzthiazuron at 1.5 kg a.i. ha^{-1} or Isoproturon at 0.75 kg a.i. ha^{-1} or metoxuron at 1.5 kg a.i. ha^{-1}, applied at 30-35 days after sowing or pendimethalin at 1.0 kg a.i. ha^{-1} applied at 2-3 days after sowing (pre-emergence).

- For controlling wild oat or mixed population of wild oat and *Phalaris minor*: Isoproturon at 0.75 kg a.i. ha^{-1} or metoxuron at 1.5 kg a.i. ha^{-1}, applied at 30-35 days after sowing.

- For controlling mixed population of broadleaf and grassy weeds: mixture of 2,4-D and isoproturon at the recommended rate of each as mentioned above.

Rice

The weed control recommendations are different for puddled transplanted and direct seeded rice.

Transplanted rice: For controlling grass weeds propanil at 8.0 l prod. ha^{-1}, applied at 10-12 days after transplanting.

- For controlling broadleaf weeds: 2,4-D at 0.5 or MCPA at 0.8 (kg a.i. ha^{-1}), applied at 25-30 days after transplanting.
  Direct seeded rice Butachlor at 1-1.6 kg a.i. ha^{-1}, applied at 4-5 days after seeding.

Maize

- For controlling broadleaf weeds: - 2,4-D at 0.5 kg a.i. ha^{-1}, applied as pre-emergence or at 10-12 cm crop height.

- For controlling grass weeds: Simazine at 1-2 kg a.i. ha^{-1}, applied as pre-emergence.

Pulses

- Nitrofen or Alachlor at the rate of 4-6 l ha^{-1} applied as pre-emergence or Treflan at 1.0 kg a.i. ha^{-1} during seedbed preparation.

Sugarcane

- For controlling grass weeds: Simazine at 2.0 kg a.i. ha^{-1}, applied as pre-emergence.

- For mixed population of broadleaf and grassy weeds:- Mix simazine at 2.0 kg and 2,4-D at 1.0 kg and apply as pre-emergence if broadleaf weeds are problem.

Future strategies

The strategies for future investigations are emphasizing the following areas.

- Herbicide technology
- Integrated weed (pest) management
- Economic analysis and policy
- Residue analysis and environmental protection and
- Training and awareness

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Prevalence and distribution of *Parthenium hysterophorus* L. in eastern Ethiopia

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Abstract

Previous reports indicated *Parthenium hysterophorus* L. is spreading very fast and is affecting plants, man and animals in eastern Ethiopia. Based on these preliminary reports, a reconnaissance study was made in some areas of eastern Ethiopia with the objective of assessing the awareness of the farmers, concerning the time and mechanism of introduction of *Parthenium* in the region; and knowhow of its economic importance. The survey showed that the weed is not still colonizing the arable land, but it is extremely abundant along roadsides, foot paths, waste lands and home yards. During the survey it was found that farmers in different areas have a differential awareness to the weed. Farmers in and around the surveyed areas did not mention as such any significant merit. Some farmers said that it can be used as a forage at early stage, but most said it has no forage value. Most of the farmers have recognized its demerit in causing irritation, affecting the flavor and color of honey and milk and is becoming a nuisance around the homeyards and cause environmental pollution. Farmers do exercise mechanical weed control using 'Dongora' or 'Machete' and sometimes hand pulling and burning, mainly focusing near the crop lands. Nevertheless, its prevalence in non-crop land permits the rapid spread and expansion of the weed. As a result, currently it entails a very good attention by all community and concerned government organizations.

Introduction

Parthenium hysterophorus L. is a noxious weed whose origin is in tropical America (1). Despite the fact that the weed is present in eastern Africa namely Kenya and Somalia, it is of a recent introduction to eastern Ethiopia.

Parthenium is in the family of Compositae. It has an extensive and deep root system that grows about 1-1.5 m wide and 0.6-1 m deep. Plant height and leaf length varies from 70 to 130 cm and from 7 to 15 cm respectively. It is an erect herb with nearly pinnated leaves. Flowering starts after a month and continued up to 78 days. The flowering and maturity are non-synchronous and life span is completed within 128 days. It produces 184.6 heads per plant and 5 seeds per head with a number of seeds amounting 923.0 per plant. The seeds of *P.hysterophorous* are light and may be dispersed by wind, water or by passing vehicles along the roadside. Seeds germinate within a week and have no dormancy (2).

It can grow under varied soil pH. The plant has a remarkable plasticity and adaptability to environmental stresses. It is photoperiodically and termoperiodically neutral, and phytosociologically rapid colonizer (3).

Its distribution in Ethiopia was reported to occur in Chercher highlands, central highlands and southern rift valley (4).

A reconnaissance study was made in most parts of eastern Ethiopia with the following objectives: a) To know the existing spatial distribution of *Parthenium hysterophorous* L. b) To assess how and when it was introduced to the region. c) To assess the awareness of the farmer towards economic importance of the weed. d) To see the current relative importance of the weed vis-a-vis other weeds. e) to get feedback from the farmers with respect to the future research and management directions.

Survey Methodology

The reconnaissance study was conducted by developing questionnaire that covers general issue about exotic weeds. The areas surveyed include: Babile, Kersa, Woter, Langie, Alemaya, Errer, Fedis, Dire Dawa and Jijiga. Most of the selected farmers for the interview, in some of the sites, were already identified farmers for the ongoing project "Improvement of management strategies of small scale farmers in uncertainties".

Table 1. Agroclimatic characters of the surveyed areas.

Characters	Woter	Langie	Dire Dawa	Alem-aya	Babile	Fedis	Errer	Jijiga	Kersa
Annual RF (mm)	780	800	400	800	682	772	520	571	856
Annual Temp. (°C)	14	13	26	16.8	23	20	22	20	16
Altitude (m)	2000	2000	1210	1980	1650	1800	1096	1096	1950

Results and Discussion

In view of the poor quarantine system in Ethiopia, it is very difficult to indicate the introduction time and place of *Parthenium* into eastern Ethiopia. Farmers said that the weed is not a recent introduction, it has been observed as early as 1975.

Surveillance studies in and around Jijiga also confirmed that, the weed might have been introduced during Ethio-Somalia war in 1976-77. Some farmers said that gun machines might carry along with them the weed seeds when they are crossing the border from Somalia to Ethiopia or transportation or commercial vehicles. Others said, nomads are responsible for introduction.

Some of the farmers did not recognize the weed as very important as compared to other problematic weeds. For instance, in some areas it is indicated that *Digitaria scalarum* is more noxious and important than *Parthenium*. This might be due to direct effect of couch grass on crop lands.

In eastern Ethiopia the weed is commonly called 'Arema Sergo' (5) and this common name may signify both exotic nature of the weed and time of introduction. In all surveyed areas the prevalence and distribution of the weed was extremely very high. It seems that its fast and robust growth helps the weed to colonize most of the areas ranging from fertile to marginal lands. It was found in all areas namely rangelands, roadways, railways, steep mountains, homeyards, footpaths, and periphery of the crop fields.

Currently the weed expansion is at an alarming rate, and is prevalent down to the Ogaden lowlands in the southeast (5) and up until to Nazret following along the railway. As indicated in the distribution map (Figure 1.), the weed is abundant in Dire Dawa, Fedis, Babile, Errer, Jijiga, Alemaya, and also in some coffee growing areas. Even settlement sites down to Jijiga are highly infested by the weed.

The infestation of the weed is very minimal in arable lands. However, this does not imply that the weed infestation remain restricted to non-arable lands. But, from the current rate of spread, most likely, it will conquer arable lands. It is not uncommon now in eastern part of east Hareige particularly around Jijiga to see both range land and crop lands being infested. As a result the nomads and the farmers are very much disturbed.

The weed seems very important naturally, since it occurs everywhere irrespective of the edaphic and agroclimatic factors. Its plasticity for different environmental condition has been clearly shown by its capacity to grow under varied soil pH, temperature and rainfall. As a consequence it grows almost from lowlands in Dire Dawa and Jijiga, medium altitudes in Alemaya to the highlands in Garamuleta. This is also supported by the capacity of the weed to germinate and grow in the range of temperature 5-30°C (6).

It has been recognized also that the weed can occur at any time throughout the year. Its colonizing capacity, natural competency and persistence is also manifested by its ability to grow in highly degraded soils where other plants are scarce. It grows even during the period when there is a very high scarcity of moisture. During the survey, it was recognized that *Parthenium* is shade sensitive, and rarely grows under shade.

As to the economic importance of the weed, the farmers witnessed that its effect on the crop is very low and insignificant because it did not yet infest the arable lands, but its effect on rangelands and waste lands has been considerable

Legend

- indicates distribution of *P. hysterophorus*

- No information from region Welwel & Warder, Kelafo, Kebri Dehar and Gode

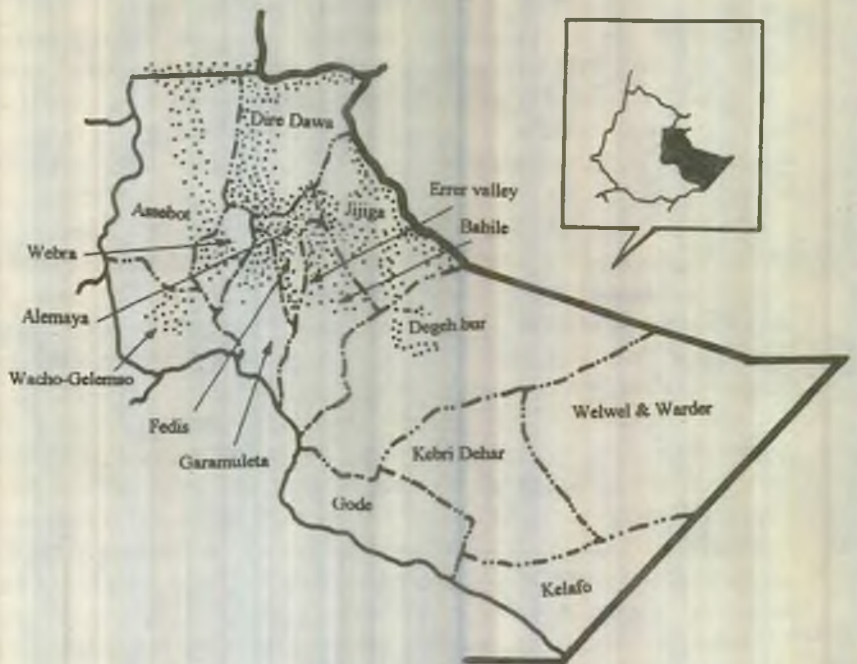

Fig. 1: Distribution map of *Parthenium hysterophorus* in eastern Ethiopia based on reconnaissance study.

and entails due attention not only by the farmer but also by non-agriculturalists. For instance, dairy cows feeding on it produce black colored milk and it tasted bitter and honey bees using *Parthenium* flowers produces bitter and changed color honey. None of the animals feed on it unless otherwise forced. Some farmers do say that, the incidence of malaria increase with the presence of *Parthenium,* though this needs further confirmation.

It was a common observation in our surveillance that no plant grew underneath or nearby it. It was also witnessed by the farmers that the weed is exceptionally dangerous and very competitive because whenever a single plant of *Parthenium* occurs in a site, it is sure that it will multiply and smother all other plants growing around it

In general farmers have currently realized that the weed is going to be very dangerous sooner or later and the awareness towards the weed is growing up as time goes on. *Parthenium* has to be considered as noxious weed due to its fast multiplication, rapid spread, agricultural and health hazard effects. It is expected that, in the future, it may have terrible health hazard effects. In India (7), several health and crop hazards due to this weed have already been recorded. Aqueous leachate of cypsella has been shown to inhibit the growth of wheat seedlings, and this signified the allelophathic potentialities of the weed (8). All parts of *Parthenium*: fruits, receptaclesand leaves support no undergrowth because those parts, including trichoms and pollen grains contain growth inhibitors that are released to the substratum via root exudation, volatilization or rain wash from aerial parts and via leaching or decomposition of dry parts in the soil or both. These toxins have been reported to inhibit the growth of bean, cowpea, sorghum and wheat (9) Greater quantity of inhibitors volatilizes from the dry parts of the weed. This volatile chemical is felt very much by the farmers when they burn it for weed control or use it for fuel wood.

Parthenium pollen inhibits pollen germinations and fruit set in *Crotalaris perillida* and *Desmodium heterocorpon*, chillies and tomato and reduce leaf chlorophyll contact in bean (10). Mixing *Parthenium* leaf material into the soil reduces emergence and plant dry weight in bean and cowpea, tillering in millet, branching in tomato, and yield in all the test species (3).

Parthenin, a sesquiterpene lectone and several phenolics, caffeic acid, vanillic acid, ferulic acid, chlorogenic acid, phydroxy benzoic acid, anisic acid are among the inhibitors identified (9). Most of them were identified in the rhizosphere. The yield in total phenolics in different parts of the weed was 1.2, 1.4, 2.73 and 2.6. in root, stem, leaf, inflorescence and cypsella respectively on dry wt. basis. The inhibitors also caused reduction in nucleic acids, proteins, reducing sugars, total and nitrate nitrogen and phosphatase. RNAse, ATPase, and IAA oxidase were among the other enzymes whose activity was enhanced; but amylase, succnic dehydrogenase (SDH), pectinase, cellulase, and nitrate reductase were inhibited. Reduction in the levels of metabolite and hormones is attributed. Reduction in the levels of metabolite and hormones is attributed to their increased leaching, inhibition of synthesis or enhanced degradations.

In case of nitrate and phosphates, it might be due to reduced uptake. All these adverse effects retarded cell division and elongation finally resulting in overall growth inhibition. These inhibitors has been reported to affect adversely the activity of free living and symbiotic nitrogen fixers and nitrifies as evidenced by culture studies and soil analysis (11).

Its effect on human being is not insignificant. It is reported in India that parthenin is a chemical responsible to cause contact dermatitis mostly to human beings. As a result of dermatitis by the weed it make hand weeding inadvisable.

Generally, the weed has detrimental effects on the germination and growth of the crop that is growing in the vicinity of the crop. Specially the young rosettes with their radial leaves closely pressed to the ground allow no other species to come up in their midst. Some studies in India (7) has shown that *P. hysterophorous* effect on human health was assumed to be more significant than its effect as a weed.

The utility of the weed is very minimal to nil. Some said that it can be used for fuel wood and as a forage during early flowering stages.

As a control measure farmers do use 'dongora' to eradicate the weed either before or after flowering, cutting using machetes or hand weeding. Of course, farmers do say that time of weed control is not as such different from other weed control practices; they normally control the weed with the other weeds during the primary cultivations time.

Conclusion

From the reconnaissance study made in eastern Ethiopia, it is very implicit that the weed is very prevalent and spread mainly in non-agricultural areas and in very low amount in arable lands.

However, its prevalence in non-arable lands is not attesting its harmlessness but rather it is very dangerous as its effect has been well indicated in the results and discussion. The availability of the weed in the non-crop lands has resulted in the high rate of unsightly expansion and prolific growth. Of course, for such type of weed there is no better example to this in India than the way *P. hysterophorus* L. was overlooked to become a serious menace in uncultivated areas all over the country in the past 15 years. This has caused a serious chronic skin diseases, affected animals & plants including the ecology (7).

Though the farmers, in general, rate it from medium harm to harmless, its fast multiplication, reproductive and dissemination capacity, warrants serious consideration.

The way *P.hysterophorus* is flourishing and becoming major problem in India illustrates man's indifference and negligence to solve weed problems in non-crop lands which include roadsides, rail-roads, industrial sites, power-lines, air-fields, range lands, etc. which prevails also in Ethiopia and this is objectionable because they are a good source of seed to infest the adjoining cultivated land, harbor insects and disease organisms that may spread to neighboring crop plants or sometimes become fire hazard when they get dried and, above all, creates problem for grazing animals.

In most of the visited areas, despite the noxiousness of *P.hysterophorus*, no serious measure is being taken by the farmers. However, from its fast dissemination potential the farmers should give due attention and devise the most effective preventive measures so as to curtail rapid infestation on agricultural areas and non-crop lands.

Thus, it can be inferred that, weed in non-agricultural areas are as much of a problem as in crop areas.

Future Control Strategy

In view of the possible and potential agricultural, health and environmental hazards of *Parthenium*, there has to be a concerted effects towards its eradication.

The following can be envisaged as a possible future control strategies for the control of the weed:

Cultural control: Mechanically or manually, preferable before flowering stage has to be carried out. It is advisable to wear hand gloves to avoid skin ailment during hand pulling operations. Use of hand hoe, fire, etc can be used but the operation has to be repeated very frequently until seeds in the soil are completely exhausted (18).

Biological control: It is a possible long term permanent solution to a dangerous weed problem (12).

Pathogens: It has been recorded in India that a disease which causes phyllody of floral parts finally leading to the death of the plant, is fast spreading over the densely populated areas occupied by *Parthenium*. The causative agent is Mycoplasma like organism (MLO) and it is *Parthenium* specific. Though it needs repeated and intensive studies, in our preliminary survey, we did not encounter phyllody but rather leaf rust. Despite the leaf rust the growth is still prolific.

Insects: During the survey no major insects were found which attack it. In India *Heliothis armigera*, grass hopper and aphids have been found to attack the weed. However, these, insects are of little value because of their potential to attack crops. Thus, it may be imperative, to look for potential insects in the native lands that can be used as a biological control agent.

Chemical control: In view of the health hazard it causes, *Parthenium* has to be controlled by herbicides. A whole range of herbicides can be employed depending on the crop situation. Other countries experience has shown that chemical weed control is more economical than mechanical. In the future, selection and optimization of the different type of herbicides for the different crop situation has to be investigated.

It is envisaged that the ideal solution to control *Parthenium* would therefore, be preventive, pre-emergence, slow release selective herbicides treatment and the research strategy to control the weed has to follow this line.

As most of the important effect of the weed is biochemical, it is imperative to make biochemical composition study. As a result the Biology and Chemistry laboratories of Addis Abeba University (AAU) and Alemaya University of Agriculture (AUA) are doing the chemical composition and bioassay study on *Parthenium*.

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Distribution and importance of *Cuscuta campestris* on noug (*Guizotia abyssinica* Cass.) in northwestern Ethiopia

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Abstract

A field survey was conducted and sampling was done in major noug (*Guizotia abyssinica* Cass.) growing areas of northwestern Ethiopia: Bahr Dar, Mecha, Achefer, Dera and Fogera. *Cuscuta campestris* was present in all five surveyed noug cultivation areas of the region. The highest infestation was recorded at Dera followed by Fogera and Bahir Dar. The level of infestation ranged between 26% at Mecha and 90% at Dera. There was an increase in incidence from the vegetative to the flowering stage of the crop. The highest incidence up to 20% and 9% were observed during vegetative state of the host at Fogera and Dera respectively. Whereas at the flowering stage it reached up to 90 percent at Dera and Fogera and 70% at Bahir Dar.

Introduction

Noug (*Guizotia abyssinica* Cass.) is the top ranking oil crop in Ethiopia both in terms of area coverage which account for about 56-67% of the total area and production volume. The crop is a national priority for its larger proportion of edible oil which is the major, if not the only, source of dietory fat for majority of the population. At farmers level, most of the produce is marketed to guarantee adequate cash to support low income families. It is cultivated primarily in the mid-altitude areas (1600 - 2200m) and occasionally in the lower (500-1600m) and higher (2200-3000m) altitude on almost all soil types. It is among the few crops that could survive heavy waterlogging during the mid growing season and has shrink - swell properties later at the time of maturity. The principal noug growing regions are: Shewa, Welega, Gojam and Gonder producing more than 80% of the national noug production. Despite its versatile uses the average seed yield is only 0.39 t ha^{-1} (1, 4, 5). Parasitic weeds particularly the genus *Cuscuta* is identified to be a number one constraint in noug production areas of the northwestern regions of Ethiopia (1, 2, 3, 6, 7). Yield losses due to *Cuscuta* infestation in noug fields faba bean and chick pea in this region and there is still a great potential for it to spread to further new areas and cause even greater losses (25, 27). In this situation there is a fear that crop choices in the rotation system after noug will be limited.

Materials and Methods

Field survey at the vegetative and flowering stage of noug was undertaken in 1993 in major noug growing areas of northwestern Ethiopia: Bahr Dar, Mecha, Achefer, Dera and Fogera) to determine the infestation level of *Cuscuta campestris* on noug and to identify the hot spot areas. Survey trips were planned by establishing a route through each location, based on distribution of oil crops cultivation areas of the region. In each route sampling was done from fields at 1 km distance on either sides of the main road within the radius of 0.5 km. From 240, 71, 76, 55 and 258 fields within 0.5 km radius: 40, 19, 13, 10 and 21 fields were observed in Bahr Dar, Mecha, Achefer, Dera and Fogera, respectively A total of 103 fields were used to collect information and for visual observations on the spread of *Cuscuta* and its incidence. Prevalence in each noug fields were also recorded.

Results and Discussion

The prevalence (percent of infested fields) of *Cuscuta campestris* is summarized in Table 1. Intensity of infestation of the parasite differed from one location to another. It ranged between 26% at Mecha and 90% at Dera. The highest prevalence was recorded at Dera followed by Fogera and Bahr Dar.

Observations on the incidence percent and area coverage of *Cuscuta* are presented in Table 2. Again there was a difference in the degree of incidence between different locations and between fields within the same location.

In most cases incidence was increased from vegetative to flowering stage in all the locations except at Mecha where slashing is practiced as soon as the infestation observed. At the vegetative stage the highest incidence up to 20% was observed at Fogera followed by Dera (9%). But, at the flowering stage within six weeks period of time up to 90% incidence was observed at Dera and Fogera followed by Bahir Dar (70%). This indicates the fast spreading nature of the parasite within a very short period of time. Area coverage by *Cuscuta* were also very large up to 0.6 and 0.5 ha at Fogera and Bahir Dar, respectively. This further indicates total infestation of almost one noug field. The above survey results clearly showed the hazard of the spread of this parasite and the necessity for precautions against its spread.

Table 1. Intensity of infestation of noug fields by *Cuscuta campestris* in selected locations of north western region of Ethiopia - 1993.

Locations	No. of sampled fields	No. of infested fields	Prevalence (%)
Bahir Dar	40	24	60
Mecha	19	5	26
Achefer	13	4	31
Dera	10	9	90
Fogera	21	18	86

Table 2. Range of incidence and area coverage of *Cuscuta campestris* in selected noug growing locations of northwestern region of Ethiopia - 1993

Location	Incidence (%)		Area coverage (ha)
	Vegetative	Flowering	
Bahr Dar	0.01 - 0.60	0.02 - 70.0	0.0001 - 0.525
Mecha	0.01 - 7.00	0.01 - 7.00	0.000025 - 0.003
Achefer	0.00 - 0.02	0.01 - 35.0	0.0001 - 0.043
Dera	0.16 - 9.28	0.20 - 90.0	0.0002 - 0.337
Fogera	0.01 - 20.16	0.06 - 90.0	0.0001 - 0.675

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Parasitic weeds research in Ethiopia: A review

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Abstract

Research on parasitic weeds in Ethiopia has been going on intermittently for over a decade. Due to various constraints, from the whole range of parasitic weeds meaningful research work was undertaken only on *Striga* and to some extent on *Orobanche*. This paper reviews the overall activities on parasitic weeds in Ethiopia with special emphasis to *Striga* research.

Introduction

The problem of parasitic weeds has never received enough attention until after it has become widely spread causing serious economic losses in important food crops such as sorghum, maize, finger millet etc. The occurrence of witchweeds (*Striga*) was first reported by Parker in 1969 although it is believed to have existed in the country for over 120 years (Richard et al. 1982). It is now established that at least 61 parasitic weed species from 6 different families do occur in Ethiopia parasitizing a wide range of crop and weed species. The most important among those being the witchweeds mainly *Striga hermonthica* and *S. asiatica*. *Orobanche* species (*Orobanche cernua* and *O. ramosa*) are very serious pests although they are mostly localized. *Cuscuta campestris* and *Cuscuta epilinum*, the two exotic species are known to be very damaging on noug and linseed respectively. Very little is known about the extent of mistletoe problem in the country. There is, however, unconfirmed information about some species attacking coffee and other economically important tree species. Sporadic infestation on citrus species is already documented. The potential for these species to spread and cause wide scale damage is enormous in the country where there are no established internal quarantine regulations.

The Ethiopian Weed Science Committee (EWSC) has long since appreciated the potential danger posed by the parasitic weeds to Ethiopian agriculture and has had a sub-committee monitoring their importance and seeking ways of reducing their impact. The sub-committee was active ever since its inception and played significant role by creating public awareness through workshops, seminars, and publications. Information collected through a questionnaire recently was also helpful in shading more light on the diversity and extent of the problem. Other activities included provision of advises to various organizations through publications with recommendations to Ministry of Agriculture (MOA) Quarantine

Service concerning parasitic weeds and suggestions again to MOA on methods of preventing long-distance spread of parasitic weeds.

Research on parasitic weeds in Ethiopia has been going on intermittently for over a decade. Due to various constraints, from the whole range of parasitic weeds meaningful research work was undertaken only on *Striga* and to some extent on *Orobanche*.

Striga studies upto 1986 were reviewed by Parker (1988). Field and laboratory activities have since then continued particularly on biology and control of *Striga*. However, accumulation of sound information, specially from field trials was very slow due to various reasons. The problem of *Cuscuta* and mistletoe species has the potential of becoming a serious burden in crop production and deserved due attention but has rarely been touched.

The intent of this paper is to review overall activities on parasitic weeds in Ethiopia with special emphasis to *Striga* research.

Survey

Information on importance and distribution of parasitic weeds in Ethiopia gathered through a questionnaire has revealed that many major and seriously damaging species do occur in the country, the predominant being species belonging to the genus *Striga* species particularly *Striga hermonthica,* which is an acute problem on sorghum and maize (5). *S. asiatica* was reported from many places, where it was not known to have existed before such as Bale, Sidamo, Welega, Shewa and Gojam. *S. gesnerioides* was found causing considerable damage on sweet potato in Gambella settlement areas, the only report on crop otherwise it is also known to occur in several other regions. Sporadic attack of *S. aspera* on maize is recorded from Southern Gojam and bordering parts of Welega. There are evidences that the other two species in *Scrophulariaceae (Buchnera hispida* and *Ramphicarpa fistulosa)* are fairly wide spread but never on crops.

Orobanche ramosa was found to be a considerably serious problem in crops in several more locations in Tigray and Welo in addition to its being a major constraint on solanaceous crops in State farms in the Middle Awash. Occurrence of more species in Orobanchaceae (*O. minor, Cistanche communicarpus, C. phylypea* and *C. tubulosa*) in various degrees is documented. The most wide spread species, which exists almost in all regions is *O. minor*, but is rarely a problem on crops.

There are some five indigenous *Cuscuta* species, however, it is the two exotic species (*C. campestris* and *C. epilinum*), which are quite wide spread attacking economically important crops, mainly noug and linseed. It appears that *C. campestris* does occur in almost all regions with moderate to severe infestation on crops in Gojam and Gamo Gofa. Heavy infestation of *C. epilinum* is reported from Shewa and Welega.

Very striking was the report on the wide spread nature of mistletoe problem and yet their existence was hardly known hitherto. There still could be some uncertainty as to the correct identification of the different species by the people who provided the information but there is no doubt as to their increasing presence in the natural vegetation and to some degree on economically important tree species. Five species are recognized as commonly occurring although it is believed that 25-35 more others do exist in the country. Moderate infestation of *Tapinanthus globiferus* is recorded on citrus, coffee, and some shade tree species in Northern Harerge and Welo. *Englerina woodifordioides* was found attacking shade trees in Eastern Gojam. *Phragmanthera reguralis* was also reported as a growing problem on fruit trees in Eastern Gojam, Central Shewa and Sidamo.

Host-range studies

All species of the genus *Striga* mostly parasitize cereals except *Striga gesnerioides*, which is rather a weed of leguminous crops. *Alectra vogelii*, a species from the same family - Scrophulariaceae, is also a potentially important problem on cowpea.

Results of a host range experiment revealed that, *Striga hermonthica* collected from different places and hosts was more virulent to sorghum and less so to maize. Finger millet, rice, barley and wheat have proved to be susceptible (5). However, pearl millet and tef were not attacked by any of the *Striga* samples tested. While immunity of the former rather seems to hold in the field, tef is often found infested in some regions of the country (6).

Control methods

Hand pulling trials

Hand pulling of *Striga* plants is still the most viable approach in the small scale subsistence agriculture. Using this method considerable advantage could be gained interms of reducing *Striga* seed bank in the soil in the long run. Results of field experiments have indicated that correct timing of this practice is important. Late pulling (pulling *Striga* at flowering) requires less than half the time needed for early pulling (1). Late pulling is less tedious and more manageable as one has to pull only flowering plants. It has been established that early pulling allows resprouting of more shoots, hence aggravating the problem.

Fertility studies

The tendency for reduced *Striga* infestation in response to Nitrogen was observed in trials carried out at Beles and Bir state farms. Nitrogen tended to decrease *Striga* infestation on Gambella-1107 and N-13 but its effect was more consistent on ICSV-1006 and ICSV-1007 (3).

Time of planting

At Sirinka (Northern Welo), the long season local variety 'Degelit' planted in April, suffered less *Striga* attack and gave superior yield compared to May and June planted short season varieties. Similarly, there was less *Striga* pressure on April planted maize compared to other plantings. This is interesting because local farmers claim that normally *Striga* is much more serious on early planted crop. Reports from experiences else where on time of planting are usually controversial.

Varieties

A wide range of maize varieties were tested at two state farm locations (Lower Bir and Beles). None of the test entries were resistant. Varieties: 8322-13, 8321-18, 8338-1, EAH-75 have produced higher yield inspite of heavy *Striga* incidence, suggesting their high degree of tolerance.

Work with sorghum genotypes has produced encouraging results recently. A number of varieties, including SAR-24, ICSV-1006, ICSV-1007 and some of their crosses were found to be highly promising following laboratory tests. When exposed to different *Striga* populations under glasshouse conditions some of them still maintained high level of resistance. Superior performance of varieties - ICSV - 1006 and ICSV-1007 was confirmed in field trials carried out at Lower Bir and Beles state farms.

Herbicides

2,4-D applied at 1 and 2 l Prod. ha^{-1} delayed emergence and killed top growth of *Striga*. The higher rate of the chemical applied at 5 and 8 weeks after crop emergence was particularly effective although it did not affect late season infestation. Glufosinate was effective against *Striga* early in the season. Chlorsulfuron and Dicamba have failed to show any effect on *Striga*. This is, however, contrasting to findings reported from elsewhere, which indicate that these two chemicals applied at very low rates were highly effective (2). A preliminary glasshouse observation test carried out later at Holetta Research Center has also revealed that different formulations of Dicamba were effective on *Striga*.

2,4-D applied 19 weeks after crop emergence, Dicamba and Glufosinate at their higher rates (0.50 and 2.0 kg a.i ha^{-1}) were found to be toxic to the crop.

Conclusions and recommendations

Survey

Analysis of survey results indicate that a wide range of parasitic weed species, including some species such as the mistletoes largely unknown previously are quite wide spread. The problem of *Striga* also seems to be spreading very fast as confirmed by reports of its occurrence in further new areas/regions. Highly contributing to this trend is lack of established quarantine procedures and hence free movement of farm machinery, farm produce and other materials from infested to non-infested areas should be restricted. To minimize the dissemination of parasitic weed seed, infested areas should be mapped and then strict quarantine restrictions imposed which would prohibit movement of contaminated materials from those areas.

Striga development appears to be less affected by pH or soil type and the problem is being aggravated by the continuous monocropping practice. In some state farms long time continuous cultivation of highly susceptible crop cultivars has led to excessive build up of *Striga* infestation and consequently abandonment of large acreages of land. Under such circumstances rotation into suitable trap crops or use of resistant varieties coupled with some complementary control measures such as hand pulling and/or herbicides would be helpful to bring down the infestation to manageable level.

S. hermonthica is the most serious and wide spread problem, but many other species, formerly of little or no significance such as *S. aspera* on maize and *S. gesnerioides* on sweet potato are also gaining importance. The spread and build up of these species has to be curtailed through constant monitoring and use of appropriate measures to prevent seed production and dissemination.

Striga host range study

Generally sorghum seems to be relatively more susceptible to Ethiopian population of *Striga hermonthica* compared to other crops. Pearl millet has so far proved to be immune, which makes it a potential break crop for *Striga* prone areas. The occurrence of *Striga* on tef, on the other hand is a recent development and yet it happens to be a rapidly growing problem of major concern. The increased susceptibility of tef could probably be due to either of the following reasons: a new strain evolving with a special ability to attack the crop or an accidental exposure of very susceptible tef cultivars to a highly virulent *Striga* population. In either case strong effort has to be made to make farmers and development workers aware that special attention should be given to *Striga* problem on tef and that if possible under no circumstances should seed setting by the parasite be allowed. A seemingly extreme measure in this case but which could still be reasonable considering the potential danger of the problem would be discouraging the cultivation of susceptible tef cultivars.

Varieties

Up to the early 1980s, large number of sorghum genotypes were tested without very encouraging results due to several reasons such as drought, non-uniformity of *Striga* infestation etc. However, beginning in the late 1980s, there was considerable progress made following use of new sites with more reliable rainfall and new modified field designs which helped to solve problems associated with non-uniformity of infestation. Among the sorghum varieties tested N-13, SAR-24, ICSV-1006 and ICSV-1007 were found to be promising with relatively high level of resistance. Some inconsistency was, however, observed in certain years and over locations, especially in the state farm sites, Beles and Lower Bir. The *Striga* infestation in those farms was usually extremely high and therefore less than ideal for resistance screening.

Most of the identified resistant varieties were poor in their agronomic quality. Recent attempts to improve the agronomic background of the varieties, while preserving the resistant trait, have yielded encouraging results and some of the crosses were found to be promising. While wide scale verification of already identified good performing genotypes continues, screening of sorghum germplasm for new sources of resistance will have to be intensified with more emphasis on indigenous materials.

Chemical control studies

Research efforts on the identification of systemic herbicides which could ideally translocate through the host crop and prevent initial stages of development of the parasite were not successful. A range of chemicals have, however, offered effective control of emerged *Striga*. These include oxyflourfen, glufosinate (both directed spray) and 2, 4-D. It was apparent that repeated application of the herbicides could be required for better results. It is worth noting here that there could only be a long term benefit from use of such chemicals through prevention of seed setting leading to gradual exhaustion of the seed bank in the soil. Herbicides may find application especially in big commercial farms where use of manual labor could be impractical. Herbicide research will have to continue with a primary objective of identifying effective chemicals with the potential of arresting early development of *Striga*.

Hand pulling trials

Hand pulling is the most commonly used control practice by the farmer but timing of the operation varies from place to place. Correct timing of this exercise appeared to be important and considerable advantage has been gained interms of saving time and efficiency from pulling late. Hand weeding of *Striga* has to be repeated at certain time intervals and has to continue upto and beyond harvest for better results. Further experiments need to be carried out on hand weeding to determine the optimum interval of time of pulling without the risk of allowing *Striga* to produce and shed seed. The practice should also be studied in integration with other control methods in the attempt to develop an integrated *Striga* control package.

Time of planting

Results of time of planting experiments were usually inconclusive and have never showed any clear trend. Research needs to be resumed to determine the interaction between rainfall intensity pattern (Bi-and mono-modal) and *Striga* infestation, which would help to decide on the optimum time of planting vis-a-vis *Striga* problem in a given region.

Fertility studies

A clear tendency of reduced *Striga* infestation was observed due to nitrogen from inorganic fertilizers. The effect of nitrogen was more pronounced on some varieties than others. Fertilizer resulted in improved yield and less *Striga* incidence on ICSV-1006 and ICSV-1007. Further studies should be conducted on different forms of nitrogen fertilizers to determine the fertilizer type - cultivar - *Striga* interaction.

Finally, it should be once again mentioned that the problem of parasitic weeds is already so diverse and quite wide spread. *Striga* is causing heavy crop losses in the low and mid altitude areas of the country where there are little or no alternative crops other than sorghum. Unless an all-out campaign with an intensified awareness program is launched to sensitize the public about the extent of the problem and the potential risks involved the problem will further spread and build up to create a situation for which any practical solution will be hard to come by. Therefore, the first step to avoid this problem would be a due attention to the problem from all concerned institutions. A visible impact can only be achieved through broad based, and concerted multi-institutional effort.

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The critical period of weed control in cotton at Abobo

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Abstract

Field studies were conducted in 1988 and 1989 at Abobo Agricultural Research Center (Gambella) to investigate the critical period of weed control in cotton yield, determine the optimum time and frequency of weed removal and estimate the extent of yield loss incurred due to weed competition. The yield of a single weeding at 15 days after emergence (DAE) of cotton gave statistically lower yield than a single weeding at either 30, 45 or 60 DAE while the latter are not significantly different in yield from twice or three times weedings. Average yield loss due to season-long weed interference was 77.4%.

Introduction

In Ethiopia, Cotton is probably the second important cash crop next to coffee (7) and at Gambella it has become an important cash crop since the establishment of the settlement program and the Abobo state farm in 1985.

Weeds in cotton cause adverse effects such as reduced yields, increased insect and disease incidence, and interference with cultural practices. Yield reduction by weeds in cotton is caused mainly by competing the crop for nutrients, moisture, sunlight, and space (3).

Cotton has a characteristic of slow early growth which favors early and vigorous weed competition (2). Severe crop losses occur when weeding is neglected or delayed. At Abobo, weeds are not adequately controlled for there is shortage of labor due to overlapping of cotton weeding with other farm operations and labor inefficiency due to malaria and adverse weather conditions. In most cases weeding is done either too early before the weeds can cause damage to the crop or too late when the competition has already taken over.

The critical period of crop-weed competition on cotton varies with varying environments, weed species, weed population, time of weed establishment, and crop varieties (4). At Melka Werer the critical period of cotton-weed competition was reported to be between 30 and 60 DAE (7). The most dominant weeds at Melka Werer are *Abutilon* sp., *Launea cornuta*, *Cyperus esculentus*, and *Cyperus rotundus* (6) while *Sorghum arundinaceum*, *Rottboellia cochinichinensis*, *Corchorus* *oliterous*, *Celosia trygina*, *Boerhaavia erecta* and *Commelina* sp. are the most dominant ones at Abobo (1,8). At Abobo, the time during which weeds cause an adverse effect to cotton yield was not known. Hence, more information on the influence of weed interference upon cotton yield is needed. Such information could be used in the development of an integrated weed management system in cotton production. Therefore, the objectives of this study were to investigate the critical period of weed control in cotton yield, determine the optimum time and frequency of weed removal and estimate the extent of yield loss incurred due to weed competition.

Materials and Methods

The experiment was conducted in 1988 and 1989 at Abobo Research Center, Gambella region in South western Ethiopia. The treatments consisted 10 levels of weeding frequencies at different times of the crop cycle and untreated weedy check plots (Table 2). Trials were established in a randomized complete block design in four replications. Cotton variety Acala 1517/70 was planted in rows at a spacing of 80 cm between rows and 25 cm between plants. Cotton yield was determined from inner rows and statistically analyzed. The extent of yield loss due to treatment effect was estimated by comparing the yield of the best treatment with that of the weedy check. The cost and net return of each treatment was determined by comparing the cost of hand weeding in different frequencies of weedings assuming Birr 2.50 manday^{-1} for labor cost. Seed cotton price was Birr 100 quintal^{-1}.

Results and Discussion

The amount of rain received in 1988 was poorly distributed than that of 1989 (Table 1). The difference in cotton seed yield was significant (P= 0.01) in both years (Table 2). Higher seed cotton yield was obtained in 1989 than 1988. This could be attributed to poor distribution of rain received during 1988. The lower amount of rain received before planting in 1988 allowed most of the weeds, which could have been controlled during land preparation, to emerge after planting. Hence, the plant was exposed to higher weed competition at an early stage. This is in agreement to what Chris Parker observed at a herbicide trial of the Agricultural Mechanization Corporation at Abobo that delayed cultivation in early June destroyed most of the weed population and allowed easy crop establishment (1).

The weedy check treatment yielded the least in both years while the weed free check gave on the average the highest yield. A single weeding at 15 DAE gave significantly lower yield than all of the other single weeding in both years. Although, not at significant level the earlier single weeding gave higher average yields than the latter. Again, a consistent yield increase was obtained (but not of significant level) (P= 0.05), with the different frequencies of weed removal (ranging from a single weeding at 30 DAE (Table 2) to 2 weedings at 30 and 45 DAE or 3 weedings at 30, 45 and 60 DAE). Table 2 also shows cost of weeding of the various treatments employed. A single weeding at 60 DAE, although is in non-significant yield range, absorbed the highest labor cost than the other single weedings at 30 or 45 DAE. The average expenditure of labor cost for one hectare in 1988 was more by Birr 32.61 than in 1989. The weed free check gave the highest yield in both years but is associated with higher labor cost and gave less net return than four of the five twice- and trice-hand weeding treatments.

Like the results of Tadesse et. al (1982) (7), the critical period of weed competition lies between 30 and 60 DAE. This is confirmed by the significant increase in yield of single hand weeding at 30 DAE over that of 15 DAE, (Table 2) and continuing with out significant change up to 60 DAE. When no weeding is done the yield loss was 69.6% in 1988, 83.2% in 1989. The average seed yield loss for both years is 77.4%.

Table 1. Monthly rainfall (mm) at Abobo Research Center in 1988 and 1989.

Month	1988	1989
January	0	0
February	0	0
March	0	80.6
April	0	136.5
May	141.1	161.4
June	108.5	137.0
July	280.3	103.2
August	241.6	225.6
September	199.3	54.4
October	0	99.2
November	18.9	19.9
December	9.3	20.5

Table 2. The effect of crop-weed competition on cotton seed yield, cost and net return of weeding treatments.

Weeding operation (DAE)*	Seed yield (kg ha^{-1})			Cost of weeding (Birr ha^{-1})			Total price (Birr ha^{-1})	Net return (Birr ha^{-1})
	1988	1989	mean	1988	1989	mean	mean	mean
Weedy check	811	635	723	-	-	-	723	723
15	1586	1905	1746	85	76	81	1746	1665
30	2183	3102	2643	78	74	76	2643	2567
45	2321	2876	2599	97	95	96	2599	2503
60	2079	2827	2453	151	138	145	2453	2308
15 and 30	2590	3438	3014	94	84	89	3014	2925
30 and 45	2396	3394	2895	156	169	163	2895	2732
45 and 60	2459	3449	2954	159	104	132	2954	2822
15, 30 and 45	2669	3680	3175	265	153	209	3175	2966
30, 45 and 60	2658	3576	3117	124	194	159	3117	2958
Weed free check	2611	3773	3192	561	326	443	3192	2749
Mean	2215	2969	2592	161	128	144	2592	2447
LSD (0.05)	489	535	355					
C.V (%)	15.28	12.52	13.71					

*DAE = Days after crop emergence

Conclusion

The period during which weed competition is associated with decreased yields is known. Though not significant, a consistent yield increase is noted in going from one to three times hand weeding. Should only a single weeding be done for some reason, it should be scheduled between 30 and 60 DAE.

As a follow-up work the crop loss due to delaying weeds after 60 DAE need to be determined since this study clearly showed that the yield sink from a single weeding at 45 DAE compared to a single weeding at 60 DAE was not significant (P= 0.05).

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Evaluation of lentil weed management practices under various tillage systems

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Abstract

To investigate the efficacy of different weed management practices under conventional tillage (CT), minimum tillage (MT) and Zero tillage (ZT); an experiment was carried out between 1989 to 1992 on light soil fields of Debre Zeit Agricultural Research Center. The main effect of tillage (T), weed control practice (W) and the TW interaction were significant. As a whole MT and ZT gave significantly higher yields than CT in weed control treated plots. But, under weedy check condition, the yield differences among tillage systems were not significant.

Introduction

Lentil (*Lens culinaris*) ranks fourth in production among the traditional cultivated cool-season food legumes. The productivity of food legumes is generally very low in the Ethiopia. The national average yield of lentil for instance, is less than 600 kg ha^{-1}. This is 50% lower when compared with cereals.

Several stress factors are responsible for this low yield of the crop, of which weeds and soil moisture are the most important.

Tillage and family labor are the only means used by farmers to manage weeds in lentil fields. Tillage is usually performed by animal drawn traditional implements, but there is shortage of draft animals in the country. On the other hand in many fields lentil fields remain unweeded or hand weeding occurs very late after the weeds have already reduced the crop's yield potential. Reasons for sub-optimal weeding include: shortage of labor during the peak flush of weed growth, intense rainfall with can limit the ability to enter fields and handweed lentil and overlaplping farm activities. This trial was, therefore, designed to evaluate the efficacy of different weed management practices under three different tillage systems in lentil production.

Materials and Methods

The experiment was carried out at Debre Zeit Agricultural Research Center during 1989 crop seasons on light soil. The lentil variety, NEL-358, was planted at 70 kg ha^{-1}. The experiment was arranged in spilt-plot design with tillage systems as main plots and weed control practices as sub-plots. Plot sizes of 5x23m and 3x5m were used for the main and sub-plot treatments, respectively. The main plot treatments comprised, conventional tillage (Two plowings followed by one harrowing), minimum tillage (application of glyphosate at 4.0 l Prod ha^{-1}) and one harrowing and zero tillage (only glyphosate application at 4.0 l Prod. ha^{-1}). Glyphosate was applied 2 to 3 weeks before sowing. The sub-plot treatments were: weedy check, hand-weeding once, (30 days after planting), hand-weeding twice, (30 and 60 days after planting), terbutryn at 2.0 l Prod. ha^{-1} (applied as pre-emergence treatment) and terbutryn at 2.0 l Prod. ha^{-1} plus supplementary hand-weeding (30 days after planting). Data collected include: dry matter weed biomass, weed count and seed yield.

Results and Discussion

The dominant weed species of the trial site was *Galinsoga parviflora*. The tillage systems did not differ in their effect on density of this weed species. However, terbutryn alone or in combination with one hand-weeding significantly reduced populations of *G. parviflora* (Table 1.).

Compared with CT, ZT and MT significantly ($P \leq 0.05$) reduced the dry matter accumulation of total weeds (Table 2). This might explain why the seed yield from plots receiving either ZT or MT was significantly higher than the yield from the CT (Table 2).

Seed yields of lentil harvested from terbutryn treated plots were significantly lower than the rest (Table 1), despite the low dry matter yield of weeds on those plots. This might be attributed to slight phytotoxicity effect of the herbicide.

The main effect of tillage (T) weed control practice (W) and the TW interaction are significant. On the average, MT and ZT gave significantly higher seed yields than CT, but under weedy check condition, the yield differences among tillage systems were non-significant (Table 3).

Seed yield obtained from ZT or MT plots receiving either one or two hand-weeding were substantially higher than those obtained from the CT plots with any of the particular weed control practice (Table 3).

In view of significant cost reduction of glyphosate more attention should be given to minimum tillage systems for lentil production to reduce the demand for repeated tillage and minimizing soil erosion losses.

Table 1. Effect of weed management practices on weeds and seed yield of lentil at Debre Zeit, 1989-1992.

Weed management	DMY[1] (gm^{-2})	Weed density[2] ($No.m^{-2}$) G.p[3]	A.h	Seed yield ($kg\ ha^{-1}$)
Unweeded check	357 a	12.3 a	3.4 a	357 c
HW (30 d.a.s)	230 b	10.8 a	2.0 b	608 ab
HW (30+60 d.a.s)	107 c	11.0 a	2.2 b	647 a
Terbutryn 1 l ha^{-1}	260 b	6.5 c	1.9 b	436 c
Terbutryn + one HW	223 b	8.3 b	1.8 b	534 b
LSD (0.05)	44	1.6	0.5	82
CV (%)	47	40	60	39

[1] DMY = Dry matter yield of total weeds; HW = Handweeding; das=Days after sowing

[2] Square root transformed values

[3] Gp= *Galinsoga parviflora*; A.h = *Amaranthus hybridus*

Table 2. Effect of tillage practices on weed control and seed yield of lentil at Debre Zeit, 1989-1992

Tillage	DMY[1] (gm^{-2})	Weed density[2] G.P[3]	Seed yield ($kg\ ha^{-1}$)
Conventional	305 a	9.1 b	349 b
Minimum	209 b	10.4 a	591 a
Zero	193 b	9.8 ab	609 a
LSD (0.05)	34	0.85	60
C.V. (%)	47	40.0	39

[1] DMY = Dry matter yield of total weeds

[2] Square root transformed values

[3] G.p = *Galinsoga parviflora*

Table 3. Effect of tillage systems and weed control practices on seed yield of lentil at Debre Zeit, 1989-92.

Treatment combination	Seed yield[1] (kg ha^{-1})
CT + no weeding	233 e
CT + hand-weeding once	311 de
CT + hand-weeding twice	367 cde
CT + terbutyn+hand-weeding once	396 cde
CT + terbutryn	437 cd
MT + no weeding	530 cde
MT + hand-weeding once	763 a
MT + hand-weeding twice	798 a
MT + terbutryn + hand-weeding once	515 bc
MT + terbutryn	528 bc
ZT + no weeding	486 bcd
ZT + hand-weeding once	750 a
ZT + terbutryn + hand-weeding once	797 cde
ZT + terbutryn	637 ab
LSD (0.05)	166

[1] Means followed by the same letter are not significantly different at (P=0.05) level of the Duncan's Multiple Range Test (DMRT).

Evaluation of non-selective herbicides for use in no-tillage Tef [*Eragrostis tef* (Zucc.) Trotter]

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Abstract

An experiment was conducted at Debre Zeit Agricultural Research Center on black clay soil to evaluate two non-selective herbicides each at three rates for their effect on weed control, and growth and yield of tef. The treatments were: i) Glyphosate at 0.36 kg a.i. ha^{-1} + slashing weeds + 44.4 mandays ha^{-1} hand weeding; ii) Glyphosate at 0.72 kg a.i. ha^{-1} + 47.5 mandays ha^{-1} hand weeding; iii) Glufosinate-ammonium at 0.60 kg a.i. ha^{-1} + slashing weeds + 38.8 mandays ha^{-1} hand weeding; iv) Glyphosate at 1.08 kg a.i. ha^{-1} + 31.9 mandays hand weeding v) Glufosinate-ammonium at 1.00 kg a.i. ha^{-1} + 40.0 mandays ha^{-1} hand weeding; and vi) Glufosinate-ammonium at 1.50 kg a.i. ha^{-1} + 29.4 mandays ha^{-1} hand weeding. Weed population in terms of both counts and biomass were not affected by the treatments. *Commelina benghalensis, Rumex bequartii, Setaria pumila, Scorpiurus muricatus* and *Amaranthus* sp were the dominant weeds. With regard to relative frequency (RF) and relative density (RD), *Commelina* and *Setaria* had the highest share both at 4 and 7 weeks after the application of the herbicides. Days to heading and maturity, plant height, panicle length, panicle weight, grain and straw yield of tef were also not altered by the herbicides.

Introduction

No-tillage (NT) is defined as the use of herbicides or other methods to kill all live plants on or near the surface of the soil as possible to provide good seed placement (3). The system got wide acceptancy by farmers all over the world and large areas of conventionally tilled lands were converted to NT. A number of non-selective herbicide screening trials were made by many workers for various crops and cropping systems. Most workers recommended glyphosate (Roundup) for controlling grassy weeds and paraquat (Gramaxone) for broadleaved weeds (5, 10, 11). The rate of application for glyphosate varied from 1.7 to 4.5 kg ha^{-1} depending on types and growth of weeds. Other herbicides such as atrazine (Atrazine), alachlor (Alanex), chlorsulfuron (Glean) were also recommended to use either singly or in combination with other herbicides in many NT systems (6, 12).

An observation on the feasibility of no-tillage for tef (*Eragrostis tef* (Zucc.) Trotter] was also made recently at Ginchi and glyphosate was found to be a promising herbicide (Rezene Fessehaie, personal communication, 1991). However, NT was not evaluated for tef at major growing regions (such as Ada area) where intensive tillage is made for the crop. Hence, the objective of this study was to evaluate two non-selective herbicides each at three rates for their effect on weed population, yield and yield components of tef.

Materials and Methods

The experiment was carried out at Debre Zeit Agricultural Research Center (8° 44° N, 38° 58° E) at 1900 m above sea level. The soil at the experimental site was a Vertisol (18.18% sand, 24.12% silt and 57.70% clay). It contains 1.49% total N, 2.10% organic matter, and a pH of 7.05 (Debre Zeit Agricultural Research Center, unpublished data).

The experimental design was a randomized complete block with 4 replications. Glyphosate and glufosinate-ammonium each at three levels were applied two weeks before planting tef. Weeds appeared at the time of planting of tef were slashed from two plots just before sowing the crop to facilitate good soil contact of the seed. In addition, supplemental hand weeding was done for all treatments in early October until the crop was weed free following farmers' practice. Details of the treatments evaluated are given in Table 1.

Table 1. Details of treatments.

Treatment no.	Treatment description
1	Glyphosate 0.36 kg a.i. ha^{-1} + slashing weeds + 44.4 mandays ha^{-1} hand weeding
2	Glyphosate 0.72 kg a.i. ha^{-1} + 47.5 mandays ha^{-1} hand weeding
3	Glyphosate 1.08 kg a.i. ha^{-1} + 31.9 mandays ha^{-1} hand weeding
4.	Glufosinate ammonium 0.60 kg a.i. ha^{-1} + slashing weeds + 38.8 mandays ha^{-1} hand weeding
5.	Glufosinate ammonium 1.5 kg a.i. ha^{-1} + 29.4 mandays ha^{-1} hand weeding

All non-experimental variables were set at farmers' level. Using variety DZ-01-354 sowing was made on July 30 by broadcasting the seeds on no-tillage plots. The seed rate was 35 kg ha^{-1}; and fertilizer at 60-25 N-P kg ha^{-1} was applied using diammonium phosphate (DAP) and urea. All doses of DAP were added at planting and urea two weeks after emergence. 2, 4-D at 1.5 l ha^{-1} was sprayed on August 21.

The weed data collected include: weed fresh biomass, relative frequency (RF), or relative density (RD); crop data include: days to heading and maturity, plant height, panicle length, lodging index, panicle weight, grain yield panicle^{-1} and ha^{-1}, straw yield and harvest index. The data were evaluated using Analysis of Variance (ANOVA) for RCB design, and means were tested for difference using Duncan's Multiple Range Test (9). Weed counts were transformed by square root method and weed biomass by logarithmic method before analysis to normalize the data.

Results and Discussion

Effect on weed population. The total count and fresh biomass (m^{-2} and plant^{-1}) of weeds before and after the application of the non-selective herbicides are presented in Table 2. None of the parameters were significantly affected by the treatments and by natural variation, i.e., uniform population was observed in plots prepared for no-till. The average number of weeds m^{-2} were successively reduced from 428 (before herbicide application) to 135 (after 4 weeks) and to 77 (after 7 weeks). The increase in biomass was much higher for the above respective periods (i.e., from 91 to 152 and to 732 g m^{-2}). Hence biomass of a single weed was raised from 0.2 g (just before herbicide application) to 10 g (after 7 weeks)

The major weed species before the application of the herbicides were *Commelina benghalensis, Setaria pumila, Scorpiurus muricatus, Amaranthus sp., Sorghum arundinaceum* and *Polygonum nepalense* as far as the relative frequency and relative density are concerned (Table 3). *Commelina* was recorded from all sampled plots and contributed for 58% of the total weed population in terms of number. Considering biomass, *Commelina, Rumex, Setaria, Scorpiurus* and *Amaranthus* were dominant. *Commelina* alone took a share of over 70% of the total weed biomass. On individual plant basis, *Rumex* weighed 8 times higher than *Plantago* (the second heaviest weed) and 40 times more than *Commelina* (the most frequent and abundant in the area). *Rumex*, however, had the relative frequency and density below one percent.

The RF and RD of each weed species 4 and 7 weeks after herbicides application are presented in Table 4. Although *Commelina* had 100% frequency for all treatments at both periods, its RF ranged from 19 to 33%. Its RD, four weeks after herbicide application, varied from 80% (in plot with 0.36 kg ha^{-1} glyphosate) to 29% (1.5 kg ha^{-1} glufosinate-ammonium). Three weeks later, the RD for this species was reduced to as low as 13%. *Setaria* was another most frequent weed although its share was reduced 7 weeks after the application of the herbicides.

Among the weed species which were recorded before the application of the herbicide, *Polygonum, Sorghum* and *Brassica* were replaced by *Cyperus, Galinsoga and Echinocloa*. Seven weeks after application of the herbicides, *Cyperus* had the highest relative density (40%) in plots treated with the highest rate of glufosinate-ammonium. The grassy weeds, *Setaria* and *Echinocloa*, were also more dominant over the broadleaved weeds, (*Amaranthus* and *Galinsoga*). This reveals the weed shifts from broadleaved to grassy and sedge due to the application of non-selective herbicides.

The individual weed counts and biomass 4 and 7 weeks after the application of non-selective herbicides is presented in Table 5. On the average, the number of weeds per m^{-2} of all species 7 weeks after herbicide application was reduced compared to the number recorded 3 weeks earlier. However, fresh biomass of all weed species per m^{-2} had shown an increment up to 14 times for *Setaria* and *Galinsoga*, and 10 times for *Amaranthus* in a 3 weeks time. *Commelina* was reduced by 68% in terms of number but increased by 500% in terms of biomass in a 3-weeks period. Hence, it is considered as a major weed both before and after the application of the herbicides since biomass is more important than number in deciding the effects of weeds on crops.

In general, this work indicated that tef was highly infested with weeds at different growth stages. Weeds affect normal growth of tef more than they do to other cereals since tef is more susceptible to weeds. The crop competition coefficients to weeds are 0.76 for tef compared to 0.88 for maize and sorghum, and 0.92 for barley and wheat (7). Hence, emphasis should be given for practices involving complete control of weeds from tef fields. In agreement with this result, weed competition in many NT systems was a serious problem since complete control of weeds was not achieved (2, 4).

In this study, although glyphosate at 1.08 kg a.i. ha^{-1} did not control the weeds as needed, Bingham *et al.* (1980) indicated that many 2-month old perennial grasses were killed by only 0.28 kg a.i. ha^{-1} glyphosate. This may be due to the variation in weed species (1).

No phytotoxic injury of tef was recorded at all rates of the two herbicides. According to Sprankle *et al.* (1975), glyphosate was rapidly inactivated in the soil; as a result, plants (maize and soybean) grown after 16 days absorbed only very small quantities of the chemical from the soil. This low phytotoxity character of the herbicides is considered as an advantage since the herbicides can safely be used (without bringing considerable damage to the plant) at least at the highest rates considered in this study (1.08 kg a.i. ha^{-1} glyphosate and 1.50 kg a.i. ha^{-1} glufosinate).

Effect on growth, yield and yield components of tef. Days to heading and maturity, plant height and panicle length of tef were not significantly ($P < 0.05$) affected by the herbicides and rates used (Table 6). All plants headed within 33 to 34 days after emergence. Plants matured 2 to 6 days later for the treatment with 1.08 kg a.i. ha^{-1} glyphosate compared to other treatments. On the average, plant height at maturity was 92 cm, of which 40% was contributed by the panicle length. The differences in lodging of tef were highly significant ($P < 0.01$). Plots with lowest rate of glyphosate (0.36 kg a.i. ha^{-1}) and highest rate of glufosinate-ammonium (1.5 kg a.i. ha^{-1}) exhibited higher lodging (66 to 68%) compared to plots with 1.0 kg a.i. ha^{-1} glufosinate-ammonium (42%).

Panicle weight and grain yield per panicle were not influenced by either the two herbicides or the three rates (Table 5). On the average, grain yield of individual panicle contributed for 63% of panicle weight. As most other characters, grain and straw yields and harvest index of tef were not affected by the two herbicides tested (Table 6). The grain yield values ranged between 1.8 to 2.4 tons ha^{-1}; the maximum yield was recorded from plots treated with relatively lower rates of glyphosate (0.36 kg a.i. ha^{-1}) and glufosinate-ammonium (0.60 kg a.i. ha^{-1}). The straw yields varied between 5.4 (for 1.0 kg a.i. ha^{-1} glufosinate-ammonium) and 7.5 tons ha^{-1} (for 0.36 kg a.i. ha^{-1} glyphosate). The harvest index values also ranged from 22 (for 1.08 kg a.i. ha^{-1} glyphosate) to 27% (for 0.72 kg a.i. ha^{-1} glyphosate); the values for glufosinate-ammonium were between 23 and 25%.

Table 2. The total count and fresh biomass of weeds before and after the application of non-selective herbicides.

Treatment	Total weed count[1]			Weed fresh biomass[2]					
	before	4 weeks after application	7 weeks after	before		4 weeks after application		7 weeks after	
	-------- (No m^{-2})	------		($g\ m^{-2}$)	($g\ plant^{-1}$)	($g\ m^{-2}$)	($g\ plant^{-1}$)	($g\ m^{-2}$)	($g\ plant^{-1}$)
1	450.0	184.5	82.0	82.15	0.19	221.88	1.23	829.64	10.74
2	420.0	161.5	67.0	70.15	0.16	178.19	1.06	987.70	16.33
3	447.0	96.0	103.0	72.07	0.16	89.69	0.87	484.00	4.27
4	421.0	109.5	81.0	65.09	0.16	129.46	1.12	669.70	8.26
5	444.0	138.5	77.0	172.34	0.47	178.84	1.28	1158.50	14.89
6	388.0	118.0	52.0	83.19	0.23	116.95	1.00	267.70	5.11
Mean	428.3	134.7	77.0	90.83	0.23	152.50	1.09	732.87	9.93
CV (%)	19.24	19.1	18.5	11.45	60.49	13.37	27.06	7.49	15.16

[1] and [2] Before analyses the following transformations were made: weed count by square root method ([1]), and weed fresh biomass by logarithm method ([2]).

Note: All means in the same column are not significantly different at 5% level of DMRT.

Table 3. Weed count, relative frequency and fresh biomass (m^{-2} and $plant^{-1}$) of weed species before the application of non-selective herbicides.

Weed species	Weed Count (No m^{-2})	Relative frequency (%)	Relative density (%)	Weed fresh biomass ($g\ m^{-2}$)	Weed fresh biomass ($g\ plant^{-1}$)
Commelina benghalensis	251.50	21.6	57.71	64.06	0.26
Setaria pumila	74.67	20.7	17.43	3.28	0.04
Scorpiurus muricatus	40.33	16.2	9.42	2.38	0.06
Amaranthus sp.	15.67	9.0	3.66	1.52	0.10
Polygonum nepalense	12.83	10.0	3.00	0.55	0.04
Sorghum arunidinaceum	20.83	6.3	4.86	0.51	0.03
Brassica sp.	4.50	8.1	1.05	0.37	0.08
Cyperus spp.	6.33	5.4	1.48	3.67	0.58
Rumex bequartii	1.34	0.9	0.31	14.04	10.48
Plantago lanceolata	0.33	1.8	0.08	0.45	1.35
Total	428.33	100.0	100.00	90.83	

Table 4. Relative frequency (RF) and relative density (RD) of weed species 4 and 7 weeks after the application of two non-selective herbicides each at three rates.

Weed species*	Treatments 1		2		3		4		5		6	
	RF	RD	RF	RD	RF	RD	RF	RD	RF	RD	RF	RD
	(4 weeks after application)											
Cb	23.5	79.67	22.2	52.32	21.1	39.58	25.0	58.45	23.5	71.48	23.5	28.81
Sp	23.5	8.13	22.2	17.65	21.1	18.23	25.0	22.37	23.5	18.41	23.5	16.62
C	23.5	8.67	16.7	25.69	21.1	33.86	18.8	14.16	11.8	3.61	23.5	51.70
A	17.7	2.17	11.1	1.24	10.5	4.17	12.4	1.37	11.8	2.17	11.8	0.85
Gp	0.0	0.00	11.1	2.17	10.5	2.08	0.0	0.00	11.8	0.72	5.9	0.85
Sm	11.8	1.36	16.7	0.93	15.7	2.08	18.8	3.65	17.6	3.61	11.8	1.27
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	(7 weeks after application)											
Cb	19.1	29.26	25.0	50.75	20.0	16.50	25.0	33.33	33.33	54.55	21.0	13.46
Sp	9.4	6.10	0.0	0.0	15.0	18.45	25.0	49.38	33.33	22.08	21.0	21.15
C	19.1	45.12	12.4	28.36	20.0	47.58	12.5	9.89	16.70	20.78	10.6	40.39
A	19.1	8.54	18.8	1.49	10.0	2.91	12.5	1.23	0.00	0.00	10.6	3.85
Gp	14.2	4.88	18.8	4.48	20.0	1.94	12.5	1.23	0.00	0.00	21.0	7.69
E	19.1	6.10	25.0	14.92	15.0	12.62	12.5	4.94	16.70	2.60	15.8	13.46
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Cb = *Commelina benghalensis*, Sp = *Setaria pumila* C = *Cyperus* sp., A = *Amaranthus* sp.
Gp = *Galinsoga parviflora*, Sm = *Scorpiurus muricatus* E = *Echinocloa* sp.

Table 5. Number and weight of individual weed species 4 and 7 weeks after the application of two non-selective herbicides each at 3 rates.

Treatment No.	*Commelina* sp. TC	TW	TW/TC	*Setaria* sp. TC	TW	TW/TC	*Cyperus* sp. TC	TW	TW/TC	*Amaranthus* sp. TC	TW	TW/TC	*Galinsoga* sp. TC	TW	TW/TC	*Scorpiurus* sp. TC	TW	TW/TC
(4 weeks after application)																		
1	147.0	189.6	1.3	15.0	5.3	0.4	16.0	23.0	1.5	4.0	3.2	0.8	0.0	0.0	0.0	2.5	0.7	0.3
2	84.5	123.6	1.5	28.5	6.4	0.2	41.5	39.2	0.9	2.0	2.8	1.4	3.5	3.7	1.1	1.5	2.5	1.7
3	38.0	53.1	1.4	17.5	5.8	0.3	32.5	28.5	0.9	4.0	0.7	0.2	2.0	0.7	0.4	2.0	0.9	0.6
4	64.0	99.4	1.6	24.5	9.1	0.4	15.5	15.7	1.0	1.5	0.8	0.5	0.0	0.0	0.0	4.0	4.5	1.1
5	99.0	159.4	1.6	25.5	7.2	0.3	5.0	3.9	0.8	3.0	2.6	0.9	1.0	1.4	1.4	5.0	3.6	0.7
6	34.0	41.8	1.2	19.5	5.7	0.3	61.0	65.8	1.1	1.0	1.4	1.4	1.0	0.9	0.9	1.5	1.3	0.9
Mean	77.8	111.1	1.4	21.8	6.6	0.3	28.6	29.3	1.0	2.6	1.9	0.9	1.3	1.1	0.6	2.8	2.3	0.9
(7 weeks after application)																		
1	24.0	586.4	24.4	5.0	27.4	5.5	37.0	70.1	1.9	7.0	92.1	13.2	4.0	44.4	11.1	5.0	9.2	1.8
2	34.0	856.5	25.2	0.0	0.0	0.0	19.0	50.1	2.6	1.0	8.6	8.6	3.0	26.3	8.8	10.0	46.2	4.6
3	17.0	286.9	16.9	19.0	69.4	3.7	49.0	94.9	1.9	3.0	4.9	1.6	2.0	5.3	2.7	13.0	22.3	1.7
4	27.0	393.7	14.6	40.0	246.3	6.2	8.0	15.6	1.9	1.0	5.9	5.9	1.0	1.5	1.5	4.0	6.7	1.7
5	42.0	1008.6	24.0	17.0	115.8	6.8	16.0	21.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	2.0	13.1	7.6
6	7.0	108.4	15.5	11.0	74.5	6.8	21.0	48.7	2.3	2.0	4.2	2.1	4.0	11.6	2.9	7.0	11.4	1.6
Mean	25.2	540.1	20.1	15.3	88.9	4.8	25.0	50.1	2.0	2.3	19.3	5.2	2.3	14.9	4.5	6.8	18.2	3.2

TC = Total weed count (No m^{-2}); TW = Total weed weight (g m^{-2}); TW/TC = Single weed weight (g $plant^{-1}$).

Table 6. The effect of non-selective herbicides on days to heading and maturity, plant height, panicle length, lodging index, panicle weight, grain and straw yield and harvest index of tef plant.

Treatment No.	Days to heading	Days to maturity	Plant height (cm)	Panicle length (%)	Lodging index (g)	Panicle weight (g)	Grain yield panicle^{-1} (kg)	Grain yield ha^{-1} (kg)	Straw yield (kg ha^{-1})	Harvest index (%)
1	33.75 a	98.25 a	91.85 a	36.90 a	68.00 a	0.93 a	0.58 a	2350.0 a	7511.3 a	23.73 a
2	34.25 a	97.75 a	90.13 a	35.83 a	46.50 ab	0.91 a	0.59 a	2148.8 a	5872.3 a	27.47 a
3	33.00 a	102.25 a	94.73 a	37.03 a	55.00 ab	0.89 a	0.55 a	2033.0 a	7217.0 a	22.13 a
4	34.25 a	98.25 a	92.93 a	37.15 a	50.00 ab	0.97 a	0.62 a	2340.5 a	7242.8 a	24.47 a
5	34.75 a	96.50 a	89.15 a	36.63 a	41.50 b	0.95 a	0.60 a	1834.3 a	5388.3 a	25.49 a
6	33.00 a	100.25 a	95.85 a	37.33 a	66.00 a	0.92 a	0.56 a	2195.0 a	7319.0 a	23.17 a
Mean	33.83	98.88	92.44	36.81	54.50	0.93	0.58	2150.3	6758.4	24.41
CV (%)	5.02	6.14	5.82	6.20	18.03	21.77	22.49	13.2	16.69	13.96

Note: Means followed by same letter(s) in the same column are not significantly different by Duncan's Multiple Range Test (DMRT) at 5% level.

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Preliminary results of weed management research in barely production areas of northwestern Ethiopia

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Abstract

Some results obtained from preliminary weed management research in barley in selected areas of northwestern Ethiopia are reported.

Field survey on weeds associated with barley in Bahr Dar area in 1987 crop season indicated that the weed flora composition is mainly dominated by broadleaf weed species. In this initial survey the most problematic weeds were recorded as: *Guizotia scabra*, *Corrigiola capensis*, *Polygonum nepalense*, *Arthraxon micans*, *Trifolium* sp., *Setaria pumila*, and *Digitaria abyssinica*. Data on weed emergence pattern study at Adet during 1987 revealed that the commencement of rainfall favoured the emergence of weed seedlings than the total amount of rainfall. Higher density of weed population (810 m^{-2}) and more weed species were observed in red soils than in black soil (718 m). Frequent tillage favoured more weed species to emerge as compared to no tillage system. Nevertheless, no tillage recorded higher density of *Guizotia* and *Bidens*. In the red soil prominent weeds were *Digitaria abyssinica*, *Polygonum nepalense*, *Corrigiola capensis*, *Guizotia scabra* and *Commelina subulata* which constituted more than 88% of the total weed population. In the black soil *Commelina subulata* and *Arthraxon micans* formed around 98%.

Results of a chemical weed control trial at Adet showed the suitability of Brittox 52.5% EC (bromoxynil + ioxynil + MCPP) at 2.5 l Prod. ha^{-1} (post.em) plus supplementary hand weeding, sequential application of Brittox with Illoxan 36% EC (diclofopmethyl) at 2.5, Igran 500 FW (terbutryn) at 3.0 (pre.em) and tralkoxydim at 4.0 (post.em)(all, in l Prod.ha^{-1}).

Introduction

In the highlands of northwestern Ethiopia, area under food barley remains unchanged over years, as it is a major staple food crop. Traditionally, barley is grown in two seasons namely: main season (Abat gebs) from June to October/December and off-season barley (Mesno gebs) from October to January/February with residual moisture. The crop is grown both under mono-and double-cropping systems. During both seasons crop yield is restricted to be very low ranging from 7-9 q ha^{-1} (1,2,3). One of the major reasons for this low productivity is luck of improved weed management practices. In this paper weed control research activities carried out in some areas of northwestern Ethiopia are reviewed.

Weed surveys

Field surveys on the weeds associated with barley in Bahr Dar awraja during 1987-1988 crop seasons indicated that the weed flora composition is mainly dominated by broadleaf species (Table 1). In this initial survey the most problematic weeds were recorded as: *Guizotia scabra, Corrigiola capensis, Polygonum nepalense. Arthraxon micans, Trifolium* sp., *Setaria pumila* and *Digitaria abyssinca*. (Bekele Hunde, unpublished data).

In the present farming systems, untimely weeding and/or zero hand weeding results in severe crop weed competition. Studies on the present weeding practices in Bahr Dar awraja (Table 2) revealed that farmers in the region adopt high tillage frequencies during dry season to control perennial grasses and sedges such as *Cynodon* spp., *Digitaria abyssinica* and *Cyperus* spp. In most cases, farmers don't practice either handweeding or use weedicides for weed control in barley. This is mainly due to overlapping of field operations, unavailability of labor and weedicides (2).

Weed emergence pattern

Studies on weed emergence pattern plays a determining role in predicting weed infestations in crops and designing control methods. Results of field trials conducted from 1989 to 1990 to study the natural emergence pattern of commonly occurring weeds on black and red soils at Adet are summarized as follows:

On the black soil frequent tillage favoured the emergence of *Commelina* and *Arthraxon* in 1989 and *Guizotia, Commelina, Arthraxon* and *Hygrophilla* in 1990 as compared to the single tillage treatment. *Guizotia* and *Commelina* in both years and *Arthraxon* in 1990 were found to emerge early in the rainy season and continue to emerge up to the end of the season. *Polygonum, Caylusea, Digitaria, Setaria* and *Hygrophilla* in 1989 and *Setaria* in 1990, observed to emerge at the middle of the rainy season.

In 1989, repeated tillage on red soil favoured the emergence of *Guizotia, Commelina. Polygonum Corrigiola* and *Caylusea* as compared to the single tillage. *Guizotia, Commelina, Cyperus* and *Plantago* were observed to emerge throughout the season while *Polygonum, Datura* and *Erucastrum* emerged one month after the rain. In 1990, repeated tillage favoured the emergence of *Commelina, Guizotia,* *Digitaria, Bidens, Polygonum, Setaria, Trifolium* and *Cyperus* spp. as compared to single tillage treatment. Most of these species were observed to emerge early in the rainy season and continued till the end of the season. However, *Solanum, Trifolium, Corrigiola,* and *Galinsoga* were noticed to emerge at the middle of the rainy season. In both years and soil types, the second and third tillage decreased the density of each weed species from the first tillage.

In general, the commencement of rainfall determined the emergence of weed seedlings than the total amount of rainfall. Higher density of weed population (810 m^{-2}) and more weed species were observed in red soils than in black soils (718 m^{-2}). Frequent tillage favoured more weed species to emerge as compared to no tillage system. Nevertheless, higher density of *Guizotia,* and *Bidens* were recorded on no tillage plots. On red soils prominent weeds were *Digitaria, Polygonum, Corrigiola, Guizotia* and *Commelina* which constituted more than 88% to the total weed m^{-2}. Whereas on black soils *Commelina* and *Arthraxon* formed around 98% of the total number of weed population m^{-2}.

Chemical weed control

During 1988 to 1990 a chemical weed control trial was conducted at Adet research center to compare the performance of the most promising pre- and post-emergence herbicides against broadleaf and grass weed species.

Grain yields differed significantly amongst treatments in 1988 ($P<0.01$) and 1989 ($P<0.05$). No grain yield differences were detected in-1990 (Table 3). The results of the combined analysis indicated that grain yields ($P<0.05$) were significantly affected by herbicide treatments (Table 3).

In general, results of this trial showed the suitability of Brittox 52.5% EC (bromoxynil + ioxynil + MCPP) at 2.5 (post-em) plus supplementary handweeding, sequential application of Brittox with Illoxan 36% EC (diclofopnethyl) at 2.5 (post-em) or Igran 500 FW (terbutryn) at 3.0 (pre.em) and PP604 (tralkoxydim) at 4.0 (post.em (all in l Prod. ha^{-1})

Table 1. Major weed species recorded in barley production fields of Bahr Dar Awraja.

Weed species	Importance*
Amaranthus hybridus	2
Bidens spp	2
Commelina subulata	2
Corrigiola capensis	2
Caylusea abyssinica	2
Guizotia scabra	3
Galinsoga parviflora	3
Medicago polymorpha	2
Oxygonium sinuatum	2
Plantago lanceolata	2
Polygonum nepalense	3
Plectranthus sp.	2
Trifolium spp.	3
Arthraxon micans	3
Rumex abyssinicus	1
Avena fatua	2
Brachiaria spp.	2
Cynodon spp.	2
Digitaria abyssinica	3
Lolium temulentum	2
Cyperus spp.	2
Setaria pumila	3

* 1 = recorded as commonly occuring weed.

2 = recorded as important weed.

3 = recorded as a major problematic weed.

Source: (Bekele Hundie, unpublished data)

Table 2. Present weed control practices in main season barley of north western Ethiopia.

Time of tillage	Tillage frequency	Time of weeding	Weeding frequency	Area	Source
Oct.-Mar.	3-6	-	-	Bahr Dar	Bekele Hunde (Unpub. data)
Nov.-Feb.	3-4	ET & EJ	1-2 HW	Debre Tabor	(3)
Oct.-Mar.	3-6	-	NW	Mecha & Achefer	(2)
Nov.-Mar.	1-6	-	NW	Adet	(1)

Table 3. Effect of handweeding and herbicide treatments on barley grain yield.

Treatment	Dose (prod. l ha^{-1})	Grain Yield (Kg ha^{-1}) 1988	1989	1990	Mean
Weedy check		1323 c	1614 bc	1987	1611 bc
1 x Handweeding (HW)		1999 a	2109 ab	1870	1993 ab
2x HW		1905 ab	2282 a	2363	2150 a
Igran (pre-em)	3.0	1473 bc	2335 a	2065	1958 ab
Brittox (post-em)	2.5	1588 abc	2118 ab	1919	1876 abc
Brittox + HW		2013 a	2131 ab	2174	2106 a
2, 4-D (post-em)	1.0	1468 bc	2196 a	2073	1912 abc
2, 4-D + HW		1480 bc	2058 ab	2002	1847 abc
Illoxan (post-em)	2.5	1293 c	1407 c	1896	1532 c
Illoxan + HW		1830 ab	2333 a	1935	2033 a
Brittox + Illoxan	2.5+2.5	1656 abc	2178 a	2225	2020 a
Igran + Brittox	3.0+2.5	1403 bc	2414 a	2518	2112 a
PP604 + Brittox	4.0+2.5	2009 a	2344 a	1903	2085 a
Mean		1642	2117	2065	2265
CV%		15.07	13.24	12.00	13.5
P		0.01	0.05	NS	0.05

* Figures on the same column followed by different letters are significantly different at P level shown at the bottom of the table.

Source: (Yeshanew Ashagrie, Tilahun Geleto and Bekele Hundie, unpublished).

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Comparison of broadleaf herbicides for wheat

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Abstract

A broadleaf herbicide trial was conducted in four locations of southern region wheat-producing areas of Ethiopia in 1991 and 1992 to facilitate the selection of a range of effective broadleaf herbicides as alternatives to the previously recommended product Brittox 52.5% EC (bromoxynil + ioxynil + MCPP). Considering both grain yields and the efficacy of controlling the major broadleaf weeds encountered in wheat, the products Starane M and Banvel P exhibited superior performance to the standard check (2,4-D) under high soil fertility conditions. Thus, both products should be added to the list of broadleaf herbicides recommended for wheat production. On-farm trials will be necessary to determine the economic feasibility of these products under peasant farmers' production circumstances.

Introduction

Broadleaf weeds represent one of the major constraints to wheat production in Ethiopia (2, 3, 5). Over the past two decades, 2,4-D has been the main herbicide available to peasant farmers for use in small cereals, including wheat (8). However, 2,4-D does not give complete control of some of the major broadleaf weed species, for example *Guizotia scabra* and *Galium spurium*, and, where applied frequently in Ethiopia, has tended to shift the weed flora towards these more resistant species (7). The timing of 2,4-D application is also critical: early application can result in phytotoxic effects on the crop, while late application seriously limits the effectiveness of weed control (2).

On the state farms, Brittox 52.5% EC (bromoxynil + ioxynil + MCPP) has been one of the most widely used and effective herbicides for the control of broadleaf weeds (4). Furthermore, Brittox is included on the list of broadleaf herbicides recommended for weed control on peasant farms in Arsi Region (2). However, products containing bromoxynil, such as Brittox, were placed under restricted usage in Ethiopia during 1990, and there were few alternative recommended herbicides available in the country. There is also a critical shortage of labor for hand weeding during the peak weeding season, both on the state farms and on peasant farms (7).

Thus, it was considered important to screen a range of alternate herbicides for the control of broadleaf weeds in the major wheat growing regions of Ethiopia. It was also considered desirable to have a range of herbicides available for wheat producers to minimize the risk of developing herbicide-resistant weed biotypes as reported with increasing frequency in other countries (6, 9). Thus, this trial was conducted during 1991 and 1992 to facilitate the selection of safe and effective broadleaf herbicides for use on wheat production.

Materials and Methods

Field experiments were conducted at four trial sites in the major wheat producing areas of Southern Ethiopia (Kulumsa, Bekoji, Garadela, and Sinana) during 1991-1992. All experiments were conducted on fields that were naturally infested with a heavy population of broadleaf weed species.

The treatments comprised ten broadleaf herbicides, once hand weeding and unweedded check treatments. Details of the treatments are listed in Table 1. At all sites Brittox 52.5% EC was included as a standard herbicide check treatment.

Plot size was 3.6 x 4.0 m = 14.4m^2 and all treatments were replicated four times. All treatments were established as a randomized complete block design. The bread wheat variety Enkoy was sown at a seed rate of 150 kg ha^{-1}. Grass weeds were controlled with a blanket application of Puma Super at 1.0 l. Product ha^{-1}.

Wheat grain yield data were subjected to analysis of variance and treatments means were tested for difference using LSD test at 5% level probability. Weed count data were used to determine the efficacy of each herbicide included in this trial.

Results and Discussion

Data from 6 trials, namely Kulumsa, Bekoji and Sinana in 1991 and 1992, were analyzed for effects on wheat grain yield (Tables 2 and 3). Weed count data from Kulumsa, Bekoji and Garadela were used to determine the efficacy of each herbicide in the trial (Table 4).

The combined analysis of variance for grain yield (Table 2) indicated that site and treatment effects were both highly significant ($P<.001$). The overall mean grain yields was 3595 kg ha^{-1} with a C.V. of 14.5%. Individual site mean yields ranged from 2713 to 4500 kg ha^{-1}. The treatment by site interaction term was significant ($P<.05$), indicating differential effects of herbicides across sites. This commonly occurs in the analysis of herbicide trials as a result of differences in the weed flora across locations. However, considering the F value derived from the treatment mean square relative to the mean square for interaction, treatment effects were still highly significant (i.e. $F_{12, 60}$ =2.89, P = 0.003) despite the treatment by site interaction.

Treatment effects were summarized for each of the six trials included in the analysis (Table 3). On the basis of their effects on grain yield across the six trials, Banvel P (T4), Glean (T5), Granstar (T6), Logran Extra (T9), Starane M (T10), Brittox (T11), and Basagran KV-P (T13) performed the best. U-46 (T3), the two Duplosan formulations (T7, T8), and Flexidor (T12) performed relatively poorly in terms of grain yield. Treatment mean yields ranged from 3888 kg ha^{-1} (for hand weeding) to 3108 kg ha^{-1} (for the unweeded check). Starane M (3806 kg ha^{-1}) and Brittox (3785 kg ha^{-1}) were the 2 highest ranked herbicide treatments, while 2,4-D (3348 kg ha^{-1}) was the lowest ranked herbicide. Starane M was significantly lower yielding than Brittox in one trial (Kulumsa 1991), but the 2 herbicides did not differ in any of the other trials. Brittox produced significantly higher yields than 2,4-D in 2 trials; the Starane M treatment significantly out yielded 2,4-D in one trial. Across the 6 trials, Starane M yields ranged from 93.7 to 105.8% of the hand weeded check (mean 97.9%); the corresponding values for Brittox were from 85.3 to 107.5% (mean 97.4%).

Table 4 presents weed control data for the Kulumsa, Bekoji and Garadela sites in 1992. Data are presented in the form of percent weed control (PWC) were: PWC=100 - [(mean weed count in treated plot)/(mean weed count in control plot)] x 100

Glean and Granstar did not perform well across individual weed species, particularly for important species such as *Galium spurium* and *Solanum nigrum* (Table 4). Starane M gave excellent control of all broadleaf weed species, and was comparable to Brittox in performance, surpassing Brittox in the control of *Corrigiola capensis*. Banvel P was less effective than either Starane M or Brittox, particularly for the control of *Amaranthus* spp., but gave better control of the major weed species than the remaining herbicides.

Thus, considering both the effects on the grain yield of wheat, and their efficacy in controlling the range of broadleaf weeds encountered across all of the sites, the herbicides Starane M and Banvel P appeared promising as alternatives to Brittox. It should be noted, however, that bromoxynil-based herbicides have not been restricted in other wheat-producing countries (1), and the case of Brittox in Ethiopia should be reconsidered on the basis of its excellent performance to date.

On the basis of the initial 2 years results, a trial is being conducted in 1993 using three rates of each selected chemical (i.e. the manufacturer's recommended rate, +30% and -30%) to determine the most economic rate for use in Ethiopia, and to ensure a minimal risk of phytotoxicity in the case of accidental application of rates higher than those recommended.

Conclusions

Starane M and Banvel P exhibited excellent performance in a broadleaf herbicide trial, considering both wheat grain yield and efficacy in controlling the major broadleaf weeds in the wheat-producing southern regions of Ethiopia. However, Brittox continued to exhibit excellent broadleaf weed control, and the restrictions placed on its continued usage in Ethiopia may need to be reconsidered.

Nonetheless, Starane M and Banvel P can be recommended for broadleaf weed control for wheat production in Ethiopia, and exhibited superior performance to 2,4-D under the high soil fertility conditions used in these trials. On-farm trials will be necessary to determine the economic feasibility of these products under peasant farmers' production circumstances.

Table 1. Treatments included in the broadleaf herbicide trial.

Treat. code	Trade name	Common name and active ingredient concentration (g/l or kg l)	Recommended rate of Product (g or l ha^{-1})
1	Unweeded check	--	--
2	Hand weeding once	--	--
3	U-46[a]	2,4-D l (720 g/1)	1.1 l
4	Banvel P[b]	dicamba + MCPP (30 + 400 g/l)	3.25 l
5	Glean 75 DF[c]	chlorsulfuron (750 g/kg)	20 g
6	Granstar 75 DF[c]	tribenuron-methyl (750 g/kg)	20 g
7	Duplosan KV[a] + U-46[a]	mecoprop-P + dichlorprop-P + 2,4-D (600 g/l + 720 g/l)	21 + 1 l
8	Duplosan Super[a]	mecoprop-P + dichlorprop-P + MCPA (130 + 310 +160 g/l)	21
9	Logran Extra[d]	terbutryn + triasulfuron (600 + 40 g/kg)	250 g
10	Starane M[e]	fluroxypyr + MCPA (70 + 400 g/l)	1.0 l
11	Brittox 52.5% EC[f]	bromoxynil + ioxynil + MCPP (525 g/l)	2.5 l
12	Flexidor[e]	isoxaben (500 g/l)	1 l
13	Basagran KV-P[a]	bentazone + MCPP (250 + 375 g/l)	2.5 l

[a]BASF product; [b]Sandoz product; [c]DuPont product [d]Ciba-Geigy product; [e]Dow-Elanco product; [f]Rhône-Poulenc product

Table 2. Combined analysis of variance for grain yield of the Kulumsa, Bekoji and Sinana weed control trials (1991,1992)

Source	Degrees of Freedom	Mean Square	F Value	Prob.
Site	5	18142508.3	29.91	0.000***
Error	18	606545.8		
Treatment	12	1147230.9	4.21	0.000***
Interaction	60	39137.7	1.46	0.027*
Error	216	272501.3		

Coefficient of Variation = 14.5%

Table 3. Grain yield data for the Kulumsa, Bekoji and Sinana weed control trials (1991, 1992).

Treat. Code	Kul92	Kul91	Bek92	Bek91	Sin92	Sin91	Mean
1[a]	3190 de[c]	3308 abcd	3622 a	3428 a	3483 cd	1614 d	3108
2[b]	3715 ab	3391 abc	4020 a	3788 a	5388 a	3027 ab	3888
3	3434 bcde	3270 bcd	3668 a	3084 a	4494 abc	2136 cd	3348
4	3433 bcde	3454 abc	3975 a	3995 a	4452 abc	2751 abc	3677
5	3826 a	3319 abcd	3725 a	3629 a	4819 ab	2685 abc	3667
6	3546 abcd	3526 ab	3538 a	4100 a	4450 abc	2889 ab	3675
7	3560 abc	3177 cd	3413 a	3303 a	4175 bcd	2514 bc	3357
8	3690 ab	3025 d	3866 a	3898 a	4163 bcd	2887 ab	3588
9	3315 cde	3357 abcd	4273 a	3684 a	4845 ab	2670 bc	3691
10	3509 abcde	3178 cd	3865 a	4009 a	5200 ab	3076 ab	3806
11	3168 e	3647 a	3926 a	4565 a	4891 ab	3010 ab	3785
12	3448 bcde	3296 bcd	3504 a	3793 a	3355 d	3393 a	3465
13	3418 bcde	3355 abcd	3897 a	4007 a	4791 ab	2613 bc	3680
Mean	3481	3331	3792	3752	4500	2713	3595
C.V.(%)	7.3	7.2	17.2	13.8	16.7	18.6	
P	.026	.096	NS	NS	.015	.003	
$LSD_{(.05)}$	365	287[d]	NS	NS	1077	722	

[a] unweeded check.

[b] hand weeded check.

[c] mean values followed by the same letters (in columns) do not differsignificantly at the 5% level of the LSD test.

[d] Kulumsa 1991 means are ranked according to the LSD test at the 10% level.

Table 4. Herbicide efficacy data (PWC) for the Kulumsa, Bekoji and Garadela weed control trials (1992).

Treat. code	Product	Total broadleaf weeds												
		Kul[a]	Bk[b]	Gar[c]	Chen.[d] Gar	Poly.[e] Bk	Guiz.[f] Bk	Gal.[g] Bk	Ox.[h] Kul	Am.[i] Gar	Gal.[j] Kul	Sol.[k] Kul	Cor.[l] Kul	Er.[m] Bk
3	U-46	63	67	64	100	94	96	35	81	62	70	76	6	100
4	Banvel P	85	86	64	100	94	94	85	86	70	94	85	91	100
5	Glean	28	77	98	100	99	83	0	100	98	93	0	97	100
6	Granstar	76	72	88	67	99	85	15	97	88	97	39	34	86
7	Duplosan KV + U-46	89	89	19	89	99	98	85	94	16	97	39	66	100
8	Duplosan S	47	72	21	100	99	92	85	92	16	89	89	69	100
9	Logran E	66	64	37	100	97	85	70	91	33	97	76	81	100
10	Starane M	94	86	98	100	100	100	95	100	98	100	100	100	100
11	Brittox	94	88	100	100	99	100	95	93	100	99	100	72	100
12	Flexidor	23	69	21	100	71	81	55	93	18	80	78	72	100
13	Basagran KV-P	83	44	24	100	95	87	80	100	20	91	54	56	100
Weed/m^2[n]		251	369	244	9	131	47	20	89	232	66	46	32	7

[a] Kulumsa R.C.; [b] Bekoji substation of Kulumsa R.C.; [c] Garadela State Farm; [d] *Chenopodium* spp.; [e] *Polygonum nepalense*; [f] *Guizotia scabra*; [g] *Galium spurium*; [h] *Oxalis corniculata*; [i] *Amaranthus angustifolium*; [j] *Galinsoga parviflora*; [k] *Solanum nigrum*; [l] *Corrigiola capensis*; [m] *Erucastrum arabicum*; [n] on unweeded check at time of scoring.

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