Editor
Rezene Fessehaie

9th Annual Conference of the Ethiopian Weed Science Committee
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The Ethiopian Weed Science Committee (EWSC) was established on 23 November 1982. EWSC is a non-profit nation-wide scientific and educational organization, open to all who are interested in weeds and their control.

EWSC 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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The biology and control of Parthenium

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Abstract

Parthenium (Parthenium hysterophorus L.) - a noxious annual weed and cause of serious health hazard is quickly spreading and covering extensive areas in Ethiopia. Its prolific seed-setting ability, wide adaptability to different ecological conditions and the allelopathic effect it exhibits account for the dominating behaviour it presents on other plant species in any kind of habitat.

Suggested control measures include: hand pulling or mowing, biological control and herbicides. Hand pulling or mowing prove to be of limited value owing to the enormous amount of labor required and vulnerability of man to the various kinds of allergies caused by the weed. Biological method of control is less pursued approach, however, some success on this line is reported from Australia. The leaf feeding chrysomelid Zygogramma bicolorata and the seed feeding weevil Smicronyx lutulentus were found effective in terms of controlling the weed, without any potential danger to beneficial plant species. A better part of the work on parthenium control was on herbicides. For use under non-crop conditions dichlort (0.5 kg a.i. ha⁻¹), MSMA (2.6 kg a.i. ha⁻¹), 2, 4-D ester (0.5 percent spray concentration), terbutryne (6 kg ha⁻¹) and atrazine (1.5 kg ha⁻¹) were found effective. Control potential of dichlort and MSMA was enhanced when applied in mixture with 2, 4-D. Other chemicals which had good impact on the weed include: bromoxynil, methazole and oxadiazone in onion fields, iinuron (0.1 percent solution) in carrots, and terbacil (0.2 percent solution) in citrus orchards. High volume application of picloram and 2, 4-D mixture, 2, 4-D sodium salt (6.0 kg ha⁻¹) and 2, 4-D amine salt (5.4 kg ha⁻¹) have also showed outstanding performance against parthenium.

Introduction

Parthenium (Parthenium hysterophorus L.) - exotic noxious weed, which is believed to have originated in tropical America, is now spreading at alarming pace in Ethiopia. There is so far no information on how this weed was introduced into this country but it was first reported in 1988 from around Dire-Dawa. At present it commonly occurs all the way through Dukem, some 15 km east of Addis Abeba. It is mainly observed growing on road sides but there is unconfirmed information
about it being a weed problem of coffee in Harerge.

Parthenium also causes dermatitis and pulmonary allergy to humans which becomes sometimes fatal (8). In Poona, India, it was found that one in 60 men was allergic (8). Gupta and Sharma (1977) reported that allergy can develop on any part of the body, particularly on hands, legs, face and back, even after limited exposure to the weed. The main toxin present in the plant has a depressant effect on human nervous system (2). To the awareness of the Author of this paper there were no reports so far on allergy cases due to parthenium in Ethiopia. If allergy problem is non-existent, it could probably mean that difference in human race and/or difference in form/biotype of the weed have effects. Dale et al, 1981 have reported differences between South African and Australian parthenium in flower color and morphological characteristics. It is also possible that the weed may already be causing health problems, but victims couldn’t understand the cause of the problem and never reported. In addition parthenium is a highly competitive and devastating weed in crops. All parts of the weed contain inhibitor(s), its concentration being greatest in leaves followed by inflorescence, fruit, roots and stem (5). Even pollen of parthenium was proved to have allelopathic effect on several test species (16). These inhibitors affect other plants and may partly account for the high competitive nature. The potential of this weed as health hazard is enormous and yet its treat to agriculture is serious. In this paper attempt is made to review some of the work done on biology and control of *P. hysterophorus*.

Biology

Parthenium is a herbaceous plant belonging to the family compositae. It is an annual, procumbent, diffused leafy herb 1-1.5 m tall (sometimes reaching 2.5 m), bearing alternate, pinnatifled leaves which resemble to carrot leaves. It also has crown buds which give rise to several new shoots when the plant is mowed (5). The new shoots grow prostrate while the main stem is erect upto 1 m high. It produces flowers in small, numerous slender stalked heads in loose corymb-like cymes.

The seeds of parthenium germinate in a wide range of pH (2.5 to 10). Seed germination was minimum at pH 2.5 (10%) but increased to 100% between pH 5.5 and 7.1. Optimum temperature appeared to be 40 °C. Germination rate of seeds kept in darkness at 20 °C was high (1). Studying the emergence pattern of six major weeds, Nunez and Mata (1976) have found that parthenium, unlike the other test species, was able to emerge throughout the year. Flowering and fruiting starts when the plant is only one month old and it continues profusely for six to eight months (5). The above ground portions (leaf axils, stems and branches) carry growing points which sprout at the slightest provocation, when in touch with soil. Some investigators have established that parthenium has the capacity to produce four generations in one year. Its prolific seeding ability, the extremely light weight
of seeds armed with a pappus and their non-dormancy are some of the factors responsible for the extensive spread through natural agencies such as wind, water, birds and animals (11). Parthenium is extremely adaptable plant that can grow on any kind of soil. Williams and Groves (1980) have reported that the weed was able to germinate, grow and flower over a wide range of temperature and photoperiods. They, however, indicated that the distribution of the species may be limited seasonally by the inability of the seed to germinate in soils of low water potential and by the inability of seedlings to establish and grow at low light intensities. Parthenium first establishes itself on cleared non-crop land, such as road sides, railway yards and vacant lots. The infestation is extended gradually to cultivated fields and grass lands (5). Hasler (1976) writes that where moisture and soil conditions are suitable parthenium becomes the dominant species. It was also established that the weed can invade all sorts of crops causing a subsequent loss of yield (8).

Control

Physical method

This method involves pulling or cutting of the weed plants. Naturally this has to be done by human labor which is prone to skin allergies. If there are allergy cases and other ailments associated with parthenium in this country, this will not be a viable approach. Plants start flowering at a very young stage and continue to flower for about nine months in a year, which makes this method impractical in view of the amount of labor that would be required (8). Mowing parthenium as soon as it flowers is useful, as it prevents seed production by the weed. However, mowing results in rapid regeneration of new shoots from crown buds close to the ground which put forth a fresh flush of flowers and seeds (5). Therefore, mowing must be repeated each time a new flush of parthenium shoots is noticed. Unless repeatedly done, burning plants is ineffective as it does not destroy the underground plant parts.

Biological control

A number of disease pathogens, pests and even higher animals were observed causing a varying level of damage to parthenium. Mealy bugs and aphids were tried as biological control agents but the species tested were found to be non-specific and potentially dangerous to beneficial plants. Extensive tests on two insects, the leaf-feeding chrysomelid (Zygogramma bicolorata) and the seed feeding weevil (Smicronyx lutulentus), in Australia showed that both of them were specific to P. hysterophorus (12). Since parthenium is a relatively long lived annual plant which can germinate, grow and flower through out the year, it could probably
support a continuing population of enemies and for this reason biological control should be feasible.

Chemical control

Chemical control is a method that holds promise in terms of controlling parthenium. Large share of the work so far reported was on post-emergence herbicides. Khosla and Sobti 1979 have cautioned that herbicidal operations have to be carried out preferably at the seedling stage before flowering since this weed develops resistance to some herbicides on maturity and moreover, leaves chances for secondary germination always. Results obtained from extensive herbicide experiments are briefly reviewed as follows: diquat, unlike paraquat which was not effective on established stands, controlled all growth stages of parthenium at a rate of 0.05 to 0.1% spray concentrations (5). Diquat 0.5 kg a.i ha⁻¹ in 500 l. water with 2, 4-D (Sodium salt) 2 kg a.i ha⁻¹ showed increased efficiency (8). Results of early work on chemical control in India showed that MSMA in concentrations up to 0.8 percent and 2, 4-D ester at upto 0.5% spray concentration were particularly effective (5). Complete kill was achieved in 20-30 days and there was no appreciable regrowth. For use under non-crop conditions Muniyappa et al. (1980) and Nalamwar et al. (1981) have reported that diquat (0.5 kg a.i ha⁻¹), MSMA (2.6 kg a.i ha⁻¹), glyphosate (0.9 kg a.i ha⁻¹), 2, 4-D sodium salt (6.0 kg), 2, 4-D amine: salt (5.4 kg), dicamba (2.05 kg) and picloram (1:61 kg) applied post-emergence and atrazine (1.5 kg ha⁻¹) terbutryne (6.0 kg ha⁻¹) applied pre-emergence were most effective in controlling the weed. They further indicated that the use of pre and post emergence herbicides applied in succession was useful for better control of the weed for a reasonable period of time. Manges 1975 reported satisfactory control of parthenium with bromoxynil, methazol and oxadiazone in onion fields. Nitrofen has been less effective but still provided 80% control of the weed. Whereas linuron applied post-emergence in carrots gave effective control. Gupta and Sharma (1977) have also found 0.1% linuron spray very effective against parthenium. In 21 to 30 days it completely destroyed all stages of the weed from cotyledon to full bloom. The treated plants showed no regrowth from the crown buds. In citrus orchards terbacil at the rate of 0.2% solution completely destroyed both young and flowering plants within three weeks. It was found to be even more effective at the rate of 0.8%. Bromacil acted somewhat more quickly than terbacil on parthenium. A 0.2% spray concentration killed flowering plants of the weed in about 16 days and the non-flowering plants in about 12 days. Paraquat plus terbacil and paraquat plus bromacil mixtures were tested for use in orchards. Spray concentration of 0.1% of each component killed the weed more quickly compared with the separate application.

Watson (1979) reported excellent control of dense parthenium and residual control for upto 12 months with high volume application of picloram and 2,4-D mixture. In another experiment metribuzin applied at 1 and 2 kg a.i ha⁻¹ at
flowering was found effective and it was able to kill the weed in 25 and 15 days respectively (7). Results of pot trials by Khosla et al (1982) showed that chloroflurenol at 2-3 mg ml⁻¹ could have a good potential for the control of parthenium.

References


Water hyacinth (*Eichhornia crassipes* [Mart.] Solms) in Ethiopia

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**Abstract**

Water hyacinth (*Eichhornia crassipes* [Mart.] Solms) is a free floating aquatic plant native to northern part of south America. The introduction and rapid spread of this plant in the White Nile system has produced serious problems for the use of the river as a resource. The Ethiopian Electric Light and Power Authority (EELPA) has reported this weed as a problem disrupting its hydroelectric operation at three stations located along the Awash River, where it emerges from Koka Lake. Infestation of water hyacinth was also recorded in the Gambella area (Sobate, Baro, Gillo and Pibor Rivers), the Abay River just south of Lake Tana, and Lake Ziway and Lake Ellen in the Rift Valley. EELPA has periodically taken action to remove the weed using human labor, and while pursuing their technique acquired moderate control at considerable cost. No fully effective and suitable control measures are available up to now.

**Introduction**

Water hyacinth (*Eichhornia crassipes* [Mart.] Solms) is a native of tropical South and Central America and the larger Caribbean islands, and has been spread by man, starting about 100 years ago, to lakes and rivers of other countries having tropical conditions. The decorative nature of its flower and its prolific reproductive capacity have lead to this spread.

It was first introduced into Africa through Egypt sometime between 1879 and 1892 (Friend, 1989). Water hyacinth was first seen on the White Nile in March 1958 and its subsequent spread both up and down stream by flooding, assisted by wind, and by boats in the River Nile has been documented by Gay (1960). It has become a problem not only in Ethiopia, but in Sudan, Zimbabwe, Zambia, Egypt, India, the Philippines, Australia, the Congo, southern and western parts of the United States, among many other countries.

This paper reviews the literature on the biology and control of water hyacinth from various investigations developed outside Ethiopia.
Distribution in Ethiopia

In Ethiopia, the weed was officially reported by Dr. Asrat Felleke (agronomist and later becoming the Minister of Agriculture), Dr. Sigurd Haukason (SIDA expert on weed science) and Dr. Getachew Awoke (botanist, Addis Ababa University), who sited the plant in Koka Lake and the Awash river about 20 years ago. At this time, although the infestation was small, the appropriate authorities were notified; however no subsequent action was taken. Other than this report, sporadic visits including some clean-up attempts, have been made during 1959, 1968, 1969, 1979 and 1988. Water hyacinth is problematic not only in the Awash River, Koka Lake but in the Gambella area (Sobate, Baro, Gillo and Pibor Rivers), the Abay River just south of Lake Tana, and Lake Ziway and Lake Ellen in the Rift Valley (Ethiopian Weed Science Committee report, 1985).

There is a lack of information concerning up-to-date distribution and general economic extent of the problem in Ethiopia. Costs of control programs range from $1 million in Zaire (1956-57) to $1.5 million per year in the Sudan (1969) as reported by Friend (1989).

The Ethiopian Electric Light and Power Authority (EELPA) has reported this weed as a problem disrupting their hydroelectric operations at the three stations located along the Awash River, where it emerges from Koka Lake. The water intake points become blocked, which must be periodically closed down in order to clean out the weed. EELPA has periodically taken action in the past to remove the weed using human labor, and while pursuing this technique acquired moderate control at considerable cost. They stopped using this method about three years ago and the water hyacinth problem has reached to unmanageable proportions once again. EELPA has requested experts at various times to make recommendations for control, which have been made; however, action has not been pursued for one reason and another (Stroud and Getachew, 1989).

Biology

Water hyacinth is a perennial monocot weed of floating habit in fresh water. It belongs to the family Pontederiaceae, order Liliales, and was first described in 1924 by Martius (Friend, 1989). It is capable of reproducing both by seed and or by vegetative means; however, the vegetative method is by far the most important. New off-spring grow at the ends of the stolons (under-water stems). Using this method the plant can be the source of 65,000 off-spring during one season.

Flowering seems to be influenced more by temperature than by day length, so that local temperatures may be more important in controlling flowering periods. In the U.S.A. and India there are two periods when flowering is most intensive (pre-rains and post-rains in the case of India). After pollination by wind withered flowers bend towards the water and maturation of the capsule occurs under water, Each capsule has 3 to 452 seeds (Friend, 1989). The seed drops on the thick mat of floating material, germinates and develops into a plant with its own leaves and
root system after about 40 days. Seeds are reported to survive for up to 15 years. Although vegetative propagation is the principal means of spread, propagation by seed is important for primary infestation as well as reinfestation after successful control with herbicides (Friend, 1989). Furthermore, Friend (1989) reports that a period of drying out followed by shallow flooding and higher temperatures aids germination. This condition occurs in lakes, such as Koka Lake, during dry periods or during periods of draw down.

The roots can trap soil particles and survive, or can be rooted directly in mud via its long, fibrous, branching root system. The plant often prefers micro-habitats in rivers where the current is not too strong and where soil particles tend to settle; although the weed can exist in free-flowing water as well. In lakes, it can also be free-floating, on shore edges (often to the windward side where it is blown), and in small muddy tributaries. It can grow alone or in association with other aquatic or semi-aquatic species (Polygonum senegalense, P. pulchrum, Scirpus corymbosus, Cyperus verticillatus, Hygrophilla spinosa, Typha angustifolia, Pistia stratiotes, and Phlya modiflora). In the latter case, removal is hampered by the presence of the other species (Stroud and Getachew, 1989).

Water hyacinth has been classified as a weed because, given the situation, it can cause a large loss of water through transpiration; it interferes with navigation; it can change the ecology of the area affecting, fascioliasis disease causing organisms; it can choke irrigation systems and can interrupt hydroelectric power systems. To summarize, it can regenerate from relatively small pieces of tissue; it can rapidly colonize using vegetative reproduction; it is not limited by substrate requirements or water depth; and its growth is manifested mainly as an increment in photosynthetic area.

Control Measures

It should be noted that integrating control methods to suit any given situation is desirable and recommended. The following discussion covers each type of control measure, any combination of which can be included in a program.

Mechanical and manual control

Removal of water hyacinth by hand or machine is a relatively expensive operation but may be preferable to where plants are killed in the water leaving a large amount of decaying matter which can promote eutrophication. It is also used where the areas of infestation is not extensive, have relatively easy access and where labor is cheap. Manual removal cannot cope with extensive infestations and may be hazardous where schistosomiasis occurs. This method has been used by EELPA in the past; and although infestations were not eliminated, they were kept to manageable levels.
Specialized dredging equipment have been used to remove water hyacinth: special buckets connected to the arm of a tractor or vertical cutters which cut a swath through the stand and convey the material to the shore using a centrifugal thrower. It should be noted that mechanically removed plants can serve as an infestation source if deposited near the water and not destroyed.

Barriers, in the case of hydroelectric plants, using a screen fence set upstream, can prevent the plants from getting too close and any plants that escape and reach the station can be removed manually.

Habitat management

Habitat management may be feasible for certain types of situations or in combination with other types of control measures. For example, where water levels can be controlled, as in the case of dams and inlets, water levels can be reduced and/or drainage of shallow areas facilitated with earth works. Drainage can also be facilitated by eliminating water hyacinth infestations using herbicides in major channel areas. The now exposed areas, where water hyacinth tends to inhabit will dry up, eliminating the weed, and/or the dry areas may facilitate access to manual removal or spraying of otherwise hard to reach areas.

Silt bars or shallows within any river courseways can be eliminated using dredging; thus reducing the places where water hyacinth can establish itself. This method has been used in New South Wales, Australia with reported success (Smith et al., 1984). This was also one strategy suggested to EELPA as a possible component in an integrated control program (Stroud and Getachew, 1989).

Smith et al. (1984) also reported that a program was initiated to destroy seedlings before they propagate in order to try to exhaust the seed pool, which is major source of reinfestation. Seed pools were identified and monitored regularly for viability. Eventually the return of native grasses and other plants has made seedling establishment difficult. The local population was educated concerning the plants so that they could also maintain a vigil.

Herbicides

The choice of herbicide depends upon the magnitude of infestation, the location, the presence of susceptible crops, hazards to the environment and non-target vegetation, etc.

Many reports have indicated success in controlling water hyacinth using 2,4-D amine or ester formulations (2.2 kg ha\(^{-1}\)) and amitrole, sprayed aerially or on the ground. Aerial spraying is favored where the areas are extensive or inaccessible for ground spraying. Ground spraying is used when there is danger of contaminating susceptible crops growing nearby. The ester formulation of 2,4-D is used only on isolated infestations as it is a more volatile formulation compared to 2,4-D.
amine. Amitrole is used in areas near susceptible crops such as cotton and soybeans (Smith et al., 1984). Smith et al. (1984) reported that the combination of herbicides and drainage was so successful that water hyacinth was nearly eradicated in a three year period.

Diquat is also a successful herbicide. It is a non-selective, contact herbicide which is faster acting than 2,4-D applied at animal or human consumption for 10 days (Axelsen, S. and C. Julian, 1988).

Parker (1989) and others (Parker and Comes, 1987) recommend using glyphosate where risk of drift or contamination of susceptible plants by 2,4-D exists. A dose of 2 kg a.i ha$^{-1}$ of glyphosate is recommended, and although effective is expensive at the present time.

Mycoherbicides have relatively recently become an option. Charudattan (1989) suggests that the pathogen *Alternaria eichhornia*, a virulent pathogen of water hyacinth, occurs in Egypt and could be developed as a mycoherbicide. He suggests that it may also occur in Ethiopia as well.

Herbicides can be used in combination with biological control where by selective application, spot spraying and precise targeting, can be used to herd insects together as well as reduce plant growth, helping to increase overall plant mortality rate (Charudattan, 1989; Haag, 1986). An example of integrated control was reported by Haag et al. (1988) where half of the water hyacinth was sprayed with Rodeo (glyphosate) at the rate of 6.7 kg ha$^{-1}$, the plants died within 2 weeks. They left a short border area of the weed which had a greatly reduced expansion rate which resulted in heavy feeding damage by *Neochetina* sp. causing total decline of the weed population.

**Biological Control**

Where mechanical control is expensive and/or infeasible and where chemical control may have undesirable side effects, biological control offers a viable alternative. Biocontrol also is useful in integrated control systems.

Host specific natural enemies for biological control of water hyacinth include five insects, a mite and a fungus. The world distribution of these agents are given in Table 1. (For further information concerning biology of these agents consult paper by Harley and Wright, 1984.)

These authors state that it is difficult to assess the relative effectiveness of the different agents because some agents have been established longer than others in ongoing programs. They do say that *N. eichhornia* has been effective in many situations whereas *N. bruchi* has been established in very few countries and that there may be competition with *N. eichhornia* for pupation sites. *Sameodes* is selective in the type of plant it attacks and should be used only to complement other agents. *Orthogalmna* has also been observed to act synergistically with *N. eichhornia* and to increase attack by pathogens. *Cercospira* has been observed to severely damage water hyacinth only when climatic conditions are favorable.
It is now available in a commercial spray (Harley and Wright, 1984).

Insects such as *N. eichhornia*, *N. bruchi* and *Sameodes albiguttalis*, which are specific feeders on water hyacinth, have been successful in Sudan, India and other countries. Biological control is a relatively slow process compared to mechanical or chemical control, but is useful in minimizing vast, difficult to reach areas as well as to slow the reproductive capacity of the weed. In Sudan, the result has been less infestation of the White Nile after introduction from the U.S.A., especially in the northern reaches of the river. It is difficult to measure the effect in southern areas of the river, but less water hyacinth is floating downstream towards the north than previously (Eligani, 1989).

*N. eichhornia* and the other agents are available from the Commonwealth Institute of Biological Control (CIBC) in Trinidad.

Table 1. Distribution of agents for biological control of water hyacinth.

<table>
<thead>
<tr>
<th>Agent</th>
<th>Distribution</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Neochetina bruchi</em></td>
<td>Panama', South America', Sudan', U.S.A.</td>
<td>Weevil</td>
</tr>
<tr>
<td><em>Sameodes albiguttalis</em></td>
<td>Australia, Panama', South America', U.S.A., Zambia'</td>
<td>Moth</td>
</tr>
<tr>
<td><em>Acigona infusella</em></td>
<td>Australia', South America'</td>
<td>Moth</td>
</tr>
<tr>
<td><em>Arzama densa</em></td>
<td>U.S.A'</td>
<td>Moth</td>
</tr>
<tr>
<td><em>Orthogonalumna terebrantis</em></td>
<td>Egypt', South America', U.S.A., Zambia'</td>
<td>Moth</td>
</tr>
<tr>
<td><em>Cercospora rodmanii</em></td>
<td>U.S.A'</td>
<td>Fungus</td>
</tr>
</tbody>
</table>

*Awaiting release or establishment not confirmed

Native range

(Harley and Wright, 1984)

U.S.A. (Florida) or Australia. Each importing country should have a quarantine facility where incoming shipments of agents are unpacked and screened for any parasites, diseases or other inclusions. The facility must be insect proof and be provided with an autoclave and a fumigation chamber for safe disposal of packaging and food material sent with the shipment. A good practice is to rear imported agents through one complete generation in quarantine to facilitate
detection of parasites or pathogens. Any parasites or pathogens should be eliminated before release. Although the host specificity has been extensively checked, some countries may have other plants which they consider should be checked. If so, this should be done while the agent is in quarantine or in the country of origin prior to importation (Harley and Wright, 1984). CIBC can act as a third country quarantine, if necessary, where the agent’s introduction into a country, such as Ethiopia, is new (Parker, 1989).

Once through quarantine, the general procedure is to propagate the agents in an insectary or in field nurseries, the latter being more economical. Starter colonies are then liberated and once the agent has become established and is increasing, infested plants can be harvested and distributed to other areas infested with water hyacinth (Harley and Wright, 1984). Monitoring, although difficult, is helpful to determine whether the agent has become established and how successful it is. However, detailed monitoring of abundance, distribution and effectiveness is a major undertaking and is not essential for many programs (Harlem and Wright, 1984).

In Australia, water hyacinth weevil *N. eichhornia* and a moth *Sameodes albiguttalis* were tried but because of the success of the water management and chemical control programs there was not enough water hyacinth area to maintain populations (Smith et al. 1984).

### Potential biological control agents identified in Ethiopia

A survey carried out in the Gambella region (1970’s?) revealed a fungus *Cercospora rodmanii* which affected water hyacinth about 5-15% in places of infestation. Prevalence of the fungus was greater in areas near the river banks where plants were somewhat shaded. Aphids (species not identified) also were attracted to the plants in the shade, and infestation levels in these areas were 25-30 aphids per plant. Damage level was not recorded. A visual assessment of mite populations revealed insignificant levels. It was noted that at natural infestation levels, none of these organisms could serve as major control agents (Shola Laboratory, 1988).

Another survey (1979) revealed aphid and mite infestations on water hyacinth in the Awash River Gorge area. Although these were not specifically identified, in confined laboratory quarters, these insects produced a new generation after 9 days which considerably damaged the weed (Shola Laboratory, 1988).

### A Possible Plan of Action for Ethiopia

In other countries, scientists have found an integrated program to be most effective in controlling water hyacinth, as no single method works well on its own. An integrated program would include biological control, chemical control (if feasible),
mechanical control such as dredging, shading or smothering, cutting. In the Ethiopian context the concept of integrated control is recommended.

1. The first task is to make a map of the infested areas (by boat using transects or by using aerial photographs and infrared photography). The areas can then be typed and assigned a priority rating according to its importance and necessity for control. Then suitable control measures could be assigned to each of the identified area types:

2. As little is known on the specific nature of water hyacinth's ecology and habitat requirements on the Awash River, and given the fact that this information is crucial towards establishing a long-term control program, it is proposed that a series of studies be carried out with support from relevant institutions.

   a) Study the biology and ecology of water hyacinth in the Awash River area with the objective of understanding the sources of infestation, mapping the area as well as categorizing the environments where it is thriving. (This relates to task 1.)

   b) Identify and study any herbivores, diseases and insects that are naturally attacking water hyacinth in Ethiopia. Look into biological control program.

   c) Study potential biological control agents that could be introduced into Ethiopia. Studies would include host preferences, rearing and release techniques, adaptability, etc. (This is related to task 3.)

3. Biological control is the most complicated type measure, but could be feasible and least expensive. Biological control as used elsewhere includes spraying of fungal disease and introducing and encouraging insect pests which eat the weed (Haag 1986). The quarantine process suggested above should be used when introducing foreign species. If indigenous species can be identified and exploited, so much the better, as the danger of potential side-effects are minimized. Also there is less concern about the organism's ability to adapt to a new habitat. Thus, biological control in this case could be considered as short-term solutions. International organizations such as CIBC can be contacted for assistance.

As stated, no single control measure will eradicate water hyacinth. It should also be noted that a series of control measures must be in effect for a long period to keep it under control as it appears that its habitat is very wide, making it difficult to eradicate it completely.
Use of Water Hyacinth

Although a weed, the material once removed has been used for various purposes: it can be fermented anaerobically and used for methane gas production, or dried and burned directly. It has also been used successfully as a source of fertilizer once dried. But drying can take considerable energy (National Academy of Sciences, 1976).

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The role of the National Herbarium in weed science research in Ethiopia

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What is Herbarium?

The dictionary meaning of the word "Herbarium" is given as "a collection of dried plants arranged systematically". This definition, being very concise, does not suggest the amount and quality of work that is tied up with that of an active, and, therefore, expanding or planning to expand herbarium. A better way of describing it would be to state that:

- It is a collection of dried and pressed specimens of plants which suggests that these specimens have to be collected and pressed requiring staff and pressing equipment to do this;
- The specimens are usually mounted showing the need for mounting papers, glue, labels, etc., or otherwise prepared for permanent preservation suggesting the need for preservatives, cupboards, filing cases, personnel, etc.; and
- The collection is systematically arranged following a sequence of an accepted classification showing the need for trained personnel and a continuous influx of literature, and the room in which to keep these collections.

Collectively, the plant collections, their housing, and support equipment as well as the personnel are called a Herbarium.

The Functions of the National Herbarium

Among the major and important functions of the National Herbarium in Ethiopia, the following deserve to be mentioned here:

- To preserve information in the form of plant specimens with their accompanying data on the indigenous vegetation of the country;
- To provide the correct scientific names of both Ethiopian and exotic plants;
- To act as a centre to stimulate research into the flora of the country and to participate in the teaching of plant systematics and ecology;
- To preserve historically important specimens such as those collected by Schimper between 1837 and 1871. This also includes the acquisition of
historically valuable specimens which are technically known as types. A type specimen is the preserved material upon which the name of the plant has been fixed.

- To provide a place where people who wish to study the plants of Ethiopia and the literature about them can do so. Systematic botanists from different countries get to know each other primarily through the collections of plants in their respective herbaria and through the literature that each contributes to the flora of his/her region.
- To answer enquires about plants especially those found in Ethiopia.
- To prepare books and scientific or popular articles dealing with the plants of Ethiopia.

The Herbarium Library

The National Herbarium has a small specialized library with around 500 books, over 3000 reprints, a few journals, a complete set of maps for the country, and a collection of "grey" or "unconventional" literature on different aspects of the natural resources of Ethiopia. This is a reference library where readers can come and work but not borrow books. Presently it is being entered into a computer using DBase III+ but soon this will be converted to CDISIS and then the data in the reprints should be more readily available to users.

Collaboration in Weed Science Research

The first deliberate effort to collect and document the weed flora of Ethiopia was that undertaken by Mr. Chris Parker in 1969 who came on an FAO consultancy and travelled to many parts of the country making herbarium collections as he went. Some of this material was identified in the National Herbarium and one of us (SE) named the grass *Polypogon monspeliensis* (L.) Desf., which was a new weed for Mr. Parker. However, most of the material had to be identified outside the country as the Herbarium had neither the staff nor extensive enough collections to make authoritative identifications. One set of Chris Parker’s collection of over 500 numbers remained in Ethiopia and formed the base for the herbarium at Holetta Research center of IAR. When Chris Parker later returned to Ethiopia, he continued his close collaboration with the National Herbarium and there are many specimens of weeds collected and named by him in the Herbarium quite a number of which are important either for recording a species for the first time or considerable enlarging on the data for that species.

Shortly after this, one of us (SE) joined IAR and was at first based in Holetta Research Center. Although working in the Pasture and Forage Section, she had the pleasure of working closely with all members of the Plant Protection Department and was sometimes referred to as ‘the botanist’. This time coincided
with that of John Moore, the FAO Weed Control Expert based in Melka Werer and the present EWSC Vice-President, Ato Ermias Kebede, who was working at Holetta. John Moore collected extensively and encouraged all the IAR centers to establish small reference herbaria. Whenever possible, duplicate collections were also brought to the National Herbarium. It was also at this time that John Moore started work on a weed control handbook for the country.

All weed scientists are aware of the importance of good reference collections, but some have made major contributions to the collections of weed species through consistently good and comprehensive collection. Notable amongst these are Wondimagegn Mersie originally based in Holetta, Ahmed Sherif based in Nazareth, Betru Haile working in Arsi and Berhanu Kinfe who did his Mastrate based in Debre Zeit. Duplicates of some of these collections can be found in the National Herbarium, but the bulk of the collections were usually placed in the research center of the researcher. It is sincerely hoped that these collections are being properly maintained.

Another institution which has worked closely with the National Herbarium in studying the weed flora of Ethiopia is the research center devoted to plant protection based in Ambo. Originally called the Phytopathological Laboratory of the USSR-Ministry of Agriculture in Ethiopia. This institute has had a series of Soviet and Ethiopian weed scientists, most of whom have made herbarium collections. For the past ten years or so, these collections have been identified in the National Herbarium with duplicates of the more interesting species being incorporated into the national collection.

Since the early 1980's the National Herbarium has actively been collaborating with the Ethiopian Weed Science Committee and several of its members. It has provided and continues to provide identification services for staff who work in the major agricultural institutions of the country: Ministries of Agriculture, the Environment, State Farms and the research centers of IAR.

A particularly close working relationship has developed with the Crop Protection and Regulatory Department of MOA. All plant specimens entering or leaving the country for the National Herbarium pass through this Department and the staff of the National Herbarium contributed advice on several matters in drawing up the new plant quarantine regulations for the country. A major task of the Crop Protection and Regulatory Department is screening incoming food grains for noxious pests and weeds. The weeds are mostly in the form of fruits and seeds. Samples are frequently brought to the Herbarium but it is very difficult to get good determinations because there is neither a special seed collection nor good reference literature for this specialized work.

In a number of cases, articles that would help specialists in weed science were contributed to either the EWSC's Newsletter or the Annual Proceedings. For example, methods of recognizing the weedy members of the genus Guizotia were published in Vol. 3, No. 5, June 1987 of the Newsletter, descriptions were provided for families with weedy members in the Annual Proceedings of 1990. One of us (MT) worked closely with Chris Parker tracing the introduction and spread of the
notorious allergenic weed, Parthenium hysterophorus L. and a note on the spread of this noxious weed was provided.

The National Herbarium together with Limnologists of the Department of Biology paid several visits to the Koka Hydroelectricity Generating Station in order to investigate and observe the degree of infestation of the lake by Water Hyacinth (Eichhornia crassipes (Mart.) Solms) as the first stem in the initiation of research activities towards the eradication, control and/or utilization of this fast-spreading water weed.

Techniques for Weed Collection and Identification

In Ethiopia, the National Herbarium in Addis Abeba will always welcome good quality herbarium specimens to add to its collections. In return the staff of the herbarium will provide the sender with the identifications of the plants received. But it must be remembered that only well collected material including adequate collecting notes, can be received and added to the National Herbarium collections. The aim of any collector should be to increase knowledge and not just acquire a set of inadequate scraps of material and information. If the following procedures are followed, anyone and everyone can make good herbarium collections.

How and What to Collect

The aim is quality not quantity. First get to know the area where you are going to make your collections and then you will be able to choose good quality specimens which are representative of the plant populations in the area. Common plants are just as important to collect as rare ones and weeds are often ignored by professional collectors. At least some of the material should be collected in flower and/or fruit, but it is also good to collect weeds at seedling stage so these can be correlated with the mature plant.

If possible whole plants, including underground parts, should be collected. This is particularly important for monocotyledons like grasses and sedges. If plants are very small, several can be collected to show the range of size in the population. Enough material should be collected to fill two sheets (or more) of newspaper 28 cm x 40 cm. Large herbs can be folded or cut into portions to represent the basal, middle and upper parts of the plant. For woody plants and climbers representative branches should be cut off with a sharp knife. This material should be put into polythene bags to stop them wilting, that is unless one is carrying a portable plant press. At the same time as the plants are collected they should be given a reference number and notes on the plant recorded in the field notebook - see below. Each polythene bag can contain just one species or a small number of species from the same habitat. Full polythene bags should be placed in a shady place - in full sun the plants soon wilt and fragile parts such as petals can be shed.
As soon as possible after collecting, the plant specimens should be put into a plant press. A plant press need not be expensive or elaborate. The collected materials are arranged between papers called flimsies, each flimsie containing only one species (kind). The reference number is attached to the specimen on a label written in pencil (biro and ink run and fade easily). The number can also be written on the outside of the flimsie in the bottom right-hand corner to aid in sorting the specimens later. Care should be taken to arrange the specimens carefully so that parts do not overlap too much and delicate features like flowers are not squashed and crumpled. Very delicate flowers can be detached and placed in soft tissue or toilet paper. Once arranged in the flimsie, the plant specimen need not be handled again until it comes for identification and finally for mounting and incorporation into the herbarium. Bulky plant material, bulbs, rhizomes, juicy stems, should be sliced open before being pressed.

Once the material has been placed in flimsies, these are put into the press using cardboard ventilators and blotters to remove the moisture from the plants. The number of flimsies that can be put between two blotters will depend on the wetness of the specimens - very juicy material needs plenty of blotters to draw out the moisture while drier material, like grasses and sedges, can be packed closer together. Finally the pile of flimsies, blotters and ventilators are placed between the frames or boards and tied tightly using the straps. It is often helpful to get a friend to sit or stand on the press while it is being tied up to make sure the material is squashed as flat as possible. The press should then be put into a warm dry, and preferably windy, place. After 24 hours the press should be opened to change very wet blotters and ventilators and to remove insects such as caterpillars which would otherwise destroy the specimens.

When the checking is complete, the plants are again tied up in the press. Checking for wet blotters should be done again after 48 hours and then again at the end of a week by which time quite a number of the specimens should be dry enough to take out of the press in their flimsies. A dry specimen feels cool but not cold when touched and should stay more or less rigid when it is picked up. If any parts still feel soft or fall over limply when the specimen is held up, then it is not dry. Flimsies containing dried specimens should be tied firmly into bundles and labeled on the outside with their reference numbers so they are easy to find when identification can be started.

Field notes

A vital part of good collecting is the making of adequate field notes. The most beautifully collected and preserved specimen is scientifically useless unless it is accompanied by adequate notes. The following information has to be put on the label which accompanies any permanent botanical specimen, and the only way to get this information is to make the notes for the label at the time of collection.
A. Essential information for all specimens collected at one time and place:

*Date* (preferably according to the Gregorian calendar);

*Locality*, which is the name of the place, if it can be found on a map, or the distance and direction from a place that can be found on a map, plus the name of the Awraja and Administrative Region. This information has to be good enough to find the collecting site again if more material is required or if another botanist wants to look for the same material;

*Altitude* (if possible), as this is an important feature in Ethiopia;

*Habitat*, which should include both a comment on the topography, (steep slope, gently sloping grassland) and the vegetation type (forest, Acacia woodland, thornscrub, etc.)

B. Information to be recorded for each specimen:

*Reference number*. Each set of specimens of the same kind (species) and collected at the same time from the same locality must be given a reference number. This number is written on a piece of paper or label or tag in pencil and put with the specimens in the collecting bag and then in the flimsie and also with the field notes for that specimen in the field note book. It is only by using a reference number system that field notes can be reliably correlated with the collected material. This number plus the name of the collector(s) can be used to refer to that specimen and will distinguish that specimen from any other herbarium specimen anywhere in the world.

*Notes on the specimen*. These should record anything of importance and interest and which will help in the identification of the material later, and which are likely to be spoilt or disappear during preservation of the specimen. These include size, habit, colour, smell, etc.

*Local name and language*. A local name should only be recorded if you are sure the person giving the name is familiar with the local plants. The uncritical use of local names in Ethiopia where there are over 80 languages can create more confusion than clarity.

All the information recorded in a field note book is transferred to a herbarium label. One such label must be completed for each flimsie of specimens. When these are identified and mounted the label is placed on the bottom right-hand corner of the sheet of mounting paper.

Any material collected according to the instructions given above can be sent to the Director, The National Herbarium, Addis Abeba University, P.O. Box 3434, Addis Abeba, for identification.
Future Collaboration in Weed Science Research

Data Base

For some time now, EWSC has pointed out the need for a computerized data base on the weed flora of Ethiopia. The authors of this paper look forward to hearing about the progress of this project. It would be good for any such project to work closely with the National Herbarium, particularly in finding the correct name for a taxon and the most common synonyms used, as well as entering data from the labels on herbarium sheets.

However, such a project has to be well planned and carried out by someone who really understands both the basic rules of systematics as well as how a data base program on a computer can work. It is difficult to fit such an activity into someone's 'spare-time', and it certainly cannot be left to poorly trained technicians who have little understanding of systematics. Data bases are bulky and take up a lot of storage space in a computer. They are also good examples of adage 'garbage in - garbage out'. Unfortunately, there are too many people who think that computers are infallible. They are only as good as the people that operate them, and no one is infallible. It is thus a pleasure to announce that the National Herbarium has been approached by the Missouri Botanic Garden in the USA to join a project to set up a data base for the whole African flora. If this project materializes it will provide adequate computer hardware, a well tested and internationally recognized data base system for this type of work, and last, but by no means least, training for a graduate to set up and run this project. The National Herbarium will be happy to keep members of EWSC informed of the progress of this project as it could considerably assist the aim of EWSC to set up a data base for the weed flora of this country.

Seed Collection

A herbarium should be able to collect, keep and organize collections of all types of plant and/or plant parts. The importance of seed collections has already been stressed in describing the collaboration between the National Herbarium and the Crop Protection and Regulatory Department of the Ministry of Agriculture. Again this is often mentioned, person who looks after such a collection should also have a background in systematics so they can help in identifying incoming material. Logically, the end result of developing such a collection should be a handbook, particularly for technicians responsible for checking the health of seeds entering and leaving the country.
Handbooks and Field Guides

A number of attempts have been made to produce weed handbooks in Ethiopia, the latest being that by Ann Stroud and Chris Parker. This is a very fine looking book, but how many of you have a copy in your office? One does not even find one in the Library of the National Herbarium.

It is certainly the intentions of the National Herbarium to assist in the production of handbooks and field guides for workers. Both authors have been involved with attempts to produce weed handbooks. As mentioned earlier, 'the botanist' worked with John Moore when she was in the IAR. This was a comprehensive work which covered well over 300 species. Unfortunately the botanist was never able to get time to do the herbarium checking needed to finalize the keys and botanical descriptions to complement the information given by John Moore. However, much of the material compiled for this work is still valid, especially that on the ecology of the different species, the crops they are normally associated with and a long list of vernacular names.

Visual Aids

The National Herbarium should also look into ways of helping societies, such as EWSC develop visual aids to improve training and extension activities. Posters could be one way of alerting extension workers and farmers of particularly noxious weeds. Photographs are good, but very expensive to get printed. The National Herbarium has an experienced botanical illustrator who could assist in producing such posters under a contract arrangement.

Many senior researchers have cameras and some regularly record some of their work on slides. The National Herbarium is establishing a collection of slides to supplement the herbarium collections and add support for staff when they give lectures. It would be very good if EWSC could join in this activity so a pool of good pictures of weeds in their various stages and habitats was established.

Other ideas which come to mind where the National Herbarium could collaborate with EWSC are the making of cards or a calendar with pictures of weeds. Particularly well collected herbarium specimens should also be prepared and mounted and covered so that they can be used in demonstrations and training programmes.

Research in the Systematics and Ecology of Weeds

It is evident from the description of its functions that the National Herbarium will be of major importance to botanists, physiologists, ecologists, cytologists, etc. However, the information on medicinal uses, beneficial or adverse economic values and poisonous properties, etc., accompanying the collections would be of great
value to non-systematists. An auxiliary to the herbarium but with a more comparable function to that of a museum, will be the establishment of a National Botanic Garden. It is a pleasure to announce that the Ministry of the Environment has just given the National Herbarium its full support in identifying and developing a suitable area as a National Botanic Garden in association with the State Forestry Conservation and Development Department. The Herbarium together with the botanic garden could be sites where research into the Ethiopian Flora and vegetation could be performed.

Currently, however, anyone interested in carrying out research in the fields of systematics, biosystematics, weed biology, physiology, ecophysiology, ecology, etc. in collaboration with the staff of the National Herbarium can do so either by getting involved in the M.Sc. and Ph.D Programmes of the Department of Biology or by entering into agreements with the staff through the keeper of the Herbarium. A better understanding of environmentally safe methods for controlling weeds has to be based on a firm knowledge of their biology and ecology. For example, is the aggressive population explosion of *Carthamus lanatus* L. in the Debre Zeit area due to introgression from the crop, *C. tinctorius* L., changing ecology of the area or changes in farming practices. What is the relation between *Avena abyssinica* Hochst. ex Rich. and *A. vaviloviana* (Malz.) Mordvink and which of the two is more likely to carry the ergot fungus?

**Training in Herbarium Techniques**

Currently the National Herbarium has a number of technicians who have received training in the art of curating and routine herbarium work through working in close collaboration with the senior taxonomists of the Unit. It has also planned to further train its technical staff as well as others in herbarium management and curation through collaboration with NAPRECA (Natural Products Research Network for Eastern and Central Africa). The date and venue of the training programme will be disclosed in the future. It is suggested that research institutes and individuals who study weeds contact the National Herbarium to obtain more information about this proposed training programme.
The weed control package in the extension activities of the Ministry of Agriculture

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Abstract

After a brief description of the structure and activities of agricultural extension in Ethiopia, this paper recognizes some problems affecting the effectiveness of extension. Solutions to these problems have been implemented by the establishment of an Extension Materials Production Unit. Extension packages on "Weed Control" and "Herbicide Use" are described along with the process of their development. In conclusion it is noted that the success of these extension packages relies on continued collaboration between the Agricultural Extension Department and the various suppliers of information.

Introduction

Agricultural extension in Ethiopia, like in most developing countries, is relatively young. Advisory work in agriculture started in two regions of Ethiopia in 1952. This work was a co-operative effort between the governments of Ethiopia and the United States of America and was called the Point-Four Programme. The programme concentrated initially on assisting sheep farmers and on establishing Agricultural Youths Clubs (MOA 1984). The organizational structure and manpower at the start of the Point-Four Programme were inadequate and several changes were made during the proceeding years.

In 1966 an Agricultural Extension Service was established under the responsibility of the Ministry of Agriculture (MOA). This organization has also undergone several policy and structural changes. The most recent change involved, as in many other countries around the world, the introduction of the 'Training and Visit' (T&V) system. The T&V system was at first introduced on an experimental basis in two regions and in 1985 was established in all surplus-producing awrajas of Ethiopia. The Agricultural Extension Department is responsible for the implementation of the T&V system.
The T&V System

The objective of the system of agricultural extension is to build a professional extension service to assist farmers and to provide appropriate support for national agricultural development (Benor & Buxter, 1984).

Staff Allocation

The structure (Staff allocation) of the T&V system is:

- at the field level, multi-purpose Development Agents (DA’s) communicate direct to farmers. Extension supervisors give guidance and assistance to Development Agents in their service to farmers. Each supervisor is responsible for 7 to 10 DA’s and supervisors are Diploma level graduates from recognized Agricultural Colleges or Institutes.
- at the Awraja level, a team of 7 to 8 Subject Matter Specialists (SMs) from each technical discipline and headed by an Extension Co-ordinator provide technical support to the Awraja DA’s
- at the Regional level, a similar team of SMS’s support the Awraja SMS teams
- at Headquarter level, a further team of SMS’s support the regional teams
- at present the staff numbers directly involved in extension activities in Ethiopia are:

  Development Agents - 2,000
  Awraja Extension Supervisors - 250
  Awraja Subject Matter Specialists - 175
  HQ Subject Matter Specialists - 6

The Training System

The visit component of T&V is balanced by the training component whereby a fixed, regular schedule of training is given to extension staff. The training schedule that has been modified for Ethiopian purposes is:

**Induction Training:** Induction training is organized for technical extension staff who have recently joined the service. Induction training is conducted each year and the two-day course covers:

- introduction to concept and methods of extension
- key features of the T&V system
- role of staff within the extension network
Monthly and Quarterly Workshops: Workshops are held every three months for Awraja SMS's to update their technical knowledge and to increase their skills in developing extension messages for DA's. These are presented by Regional SMS's in collaboration, where possible, with research staff of the Institute of Agricultural Research.

Pre-season Training: This is conducted for extension staff assigned to project-financed, high intensity extension areas. Lasting for ten days in the period prior to the major agricultural season, this training is aimed at refreshing the knowledge of Awraja SMS's and is conducted by HQ and Regional SMS's and scientists from local research centres.

Special Training: MOA designs and conducts special training courses as the need arises. To date courses have been presented on such topics as "Methodology Training for Trainers" and "Training in the Use of Newly Formulated Extension packages".

The Visit System

The T&V approach requires a regular, fixed schedule of visits to farmers by DA's.

In the surplus producing areas of Ethiopia a DA is responsible for 1300 farm households. These households are split into 8 groups of around 160 households with six farmers nominated as Contact Farmers for each group.

A DA is scheduled to visit 6 Contact Farmers (one group of households) per day on a fortnightly rotation so that each group is visited once a fortnight. Eight work days per fortnight are devoted to farm visits with the remaining work days allocated to training and administrative matters. At each visit, DA's pass on production recommendations, advise farmers on solutions to field problems, and discuss agricultural activities.

In conjunction with their visit activities, DA's conduct demonstrations to support recommendations.

Demonstrations - simple, practical and low-cost technologies are demonstrated in fields of Contact Farmers. The demonstration programme was initiated three years ago. In the 1989/90 crop season 2,213 demonstrations were conducted with an attendance of 21,166 farmers at associated field days. In 1990/91, 1,000 demonstrations were conducted and materials for 4,130 demonstrations have been distributed across Ethiopia for the present season. Demonstrations have been conducted on improved varieties, fertilizer rates, seed treatments, and cultural practices (timely weeding). Crop rotations and other long term strategies are demonstrated on an on-going basis.
Improvements to the T&V System-Package Development

As has been described above, a lot of effort has been made to improve the organizational structure of the extension system within MOA during the past five years.

However, improvement of the organizational structure, by itself, does not necessarily improve the effectiveness of extension activities. Organizational structure may place DA’s in front of farmers on a regular basis, but it does not necessarily equip them with "What to Say" and "How to Say It ". The interface between Development Agents and farmers is the most crucial link in an extension network for effective extension. The problems that have been noticed within the current system are:

- the training component of the T&V system is not effective in delivering simple, practical messages to DA’s for communication to farmers.
- DA’s do not have the resources to develop extension materials to assist in the delivery of messages to farmers.
- insufficient emphasis has been placed on training DA’s in effective communication techniques.

To overcome these problems the Agricultural Extension Department of MOA has taken steps to improve support for DA’s. An Extension Materials Production Unit (EMPU) has been established to produce extension packages which incorporate:

- simple, practical extension messages
- appropriate extension materials
- instructions for delivery of messages and materials using effective communication/extension techniques.

Extension Packages

The extension packages are designed to be presented by DA’s to farmers within the framework of the T&V system. Presentation techniques are based on a participative discussion approach which encourages farmers to:

- identify specific problems
- investigate alternative solutions, and
- decide to adopt a solution appropriate to their circumstances
Extension messages are selected from existing technologies which may be implemented by farmers within the context of available resources (materials and inputs).

The process of developing a package involves consideration of the following points:

- **The audience**: who are they? where are they? what do they know and feel about the topic? what resources do they have? what limitations are there to adoption? is the package specific to a given geographical audience? etc
- **Change**: what changes need to be brought about in the knowledge, skills and attitude of the audience in order to encourage adoption.
- **Time scale**: what time must be allowed to bring about these changes, when will training be conducted?
- **Mechanism**: what mechanism will be used to bring about the change? will extra resources be employed apart from the existing extension system? (eg. mass media, special training or display units)?

A package has the following components:

**Visit Plans.** a script which gives instructions to DA's on how to present the message of a given topic. For each visit a brief description is given of objectives, location, and materials, followed by a description of the accompanying Flip Charts and their messages. The section on the Flip Charts is to assist DA's in arranging the Flips and understanding the message and sequence of each one.

Following this introductory section are the instruction on how to deliver the visit, divided into CONTENT, and METHOD.

The Content column instructs DA's in "What to Say" by giving a detailed script for the visit using headings such as "ASK this question", EXPLAIN this principle", "SUMMARIZE farmers response" etc.

The Method column instructs DA's as to "How to Say It" by listing an extension/communication technique (such as Question and Discussion, Discussion Group, Story Time etc) and naming the accompanying Flip chart to be displayed.

**Visual Aids:**

A range of simple visual aids are employed, including:

- simple black-and-white, line drawn Flip Charts which in general convey one message per picture.
- comic strips- all the flips for one visit reduced into a comic strip format with simple captions
photograph hand--rounds — photograph collages in aplastic cover which can be handed around a farmer group to create discussion and give visual support to the DA explanation

- samples - locally collected samples of weeds, crops etc which reinforce the DA's discussion
- posters - used for generating awareness and interest in a topic prior to the visit by DA's
- electronic visual aids - which are seldom used as they are inappropriate in the field context of the DA due to difficulty of maintenance and transport, and lack of electricity.

Flip Board - a wooden structure to hold the Flip Charts. The four sides of the Flip Board can be used for blackboard, flannel board and white board, as well as for Flip Chart display.

Package Development Team

The EMPU team consists of a manager, a writer, an artist and a computer/equipment operator. These people work as a multi-disciplinary team covering all agricultural topics. Technical expertise is brought to the team by temporary assignment of Headquarter SMS's and specialists from MOA Technical Departments.

After the first draft is completed it is sent back to the technical departments for comment and is field tested with a small sample of DA's and SMS's drawn from various Regions and Awrajas.

Based on feedback from the field test and technical departments, final alterations are made to the package before it is submitted for mass production (sufficient copies for all DA's and discipline-related SMS's)

Training

Training is conducted for Regional staff who pass on the training for Awraja staff. Generally SMS's, Supervisors and DA's are included in the one Awraja training. It is hoped that a better team spirit will be generated by training all Awraja staff together. All training is conducted in the same manner - the trainers present the package to the audience as though they were DA's conducting a visit to farmers. In this manner, all staff come to appreciate the level of message appropriate to farmers, and the communication techniques used in adult education.
Topics for Package Development

Topics are selected for package development on a single priority basis - what are the most important messages that can be given to Ethiopian farmers today to assist them to increase their production tomorrow in a sustainable manner within the current resource availability. Around 10 packages have so far been developed and foremost amongst these is "Weed Control" with its supporting package on "Herbicide Use".

The weed control package

The Weed Control Package was developed in collaboration with the Crop Protection and Regulatory Department and Shewa PADEP VI. It is based on four visits:

- Visit One - to create awareness of the problems created by weeds and encourage farmers to decide to improve weed control;
- Visit Two - prevention, investigate ways in which weeds can be prevented from setting seed or being introduced into the cropping situation;
- Visit Three - killing weeds, investigate ways in which yield loss can be reduced once weeds are established, concentrating on early weeding, number of weedings, chemical control, etc.;
- Visit Four - competition, investigate ways in which improved agronomic practices can be used to make the crop compete more strongly against weeds;

It is anticipated that the Weed Control Package will be distributed to all DA's this year, and that the package will be presented to an increasing number of farmers over the next 2 to 3 years with adoption occurring over a 5 year period.

Herbicide use package

The Agricultural Input Supply Corporation (AISCO) of MOA has imported significant quantities of herbicides and knapsack sprayers for the 1991/92 crop season to assist farmers in weed control. To support this supply of resources, and
to follow up the Weed Control Package, a "Herbicide Use" package was developed based on instructing farmers how the knapsack sprayers should be used to safely apply the imported herbicides.

The Herbicide Use Package consists of two visits:

- Visit One-Safe handling of herbicides
- Visit Two-Knapsack sprayers calibration.

Collaboration

The success and effectiveness of agricultural extension in Ethiopia does not hinge solely on the efforts of the Agricultural Extension Department. Effective extension depends on close collaboration between the technical departments and institutions (which know "What to Say") and the extension department (which knows "How to Say It"). Extension cannot be successful if simple, practical messages which assist farmers to improve their production are not made available to the extension service from those departments and institutions which are charged in gathering and researching such messages. Such collaboration already exists and should be reinforced in the future.

The Research and Extension Liaison Committee (RELC) has, in part, the responsibility to facilitate two-way communication between research and extension. This body is central to the planning of the demonstration programme and the supply of technology and materials, along with agricultural input organisations, such as the Seed Corporation.

The Institute of Agricultural Research directly contributes to extension services by providing its staff to assist in training extension staff.

The various technical departments of MOA directly participate in the development of extension packages by assisting in setting priorities for topic development, by providing temporary members to the package development team, and providing technical comment on the draft package.

Commercial firms, such as ICI - Plant Protection Division, also contribute technical and sales information to package development.

Conclusion

The T&V system provides a clear logical structure for the conduct of extension activities in Ethiopia. The structural system must be supported with an input of:

- extension materials
simple, practical messages for farmers
improved communication skills for all extension staff

The Extension Materials Production Unit has been established within the Agricultural Extension Department of MOA in order to provide these inputs. The Unit works in close collaboration with the various departments and organisations which have responsibility for gathering technical information. A team is formed comprising of staff from the Unit and from the technical organization. The team proceeds to:

- define simple, practical messages
- design extension materials
- incorporate effective communication techniques

With the end result being an extension packages which is passed down through the training system of the T&V system to DA's for use by them on their scheduled visits to farmers.

The success of the EMPU will depend on continued close collaboration with the organisations which can supply technical information.
Tillage and weed control effects on weed growth and yield of maize at Abobo

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Institute of Agricultural Research
P.O.Box 2003, Addis Ababa

Abstract

A tillage and weed control experiment was conducted at Abobo Research Center, South Western Ethiopia, in 1988 and 1989 to see the growth and yield response of maize to tillage practices, and to compare a pre-emergence herbicide with different hand weeding regimes for weed control. A statistically non-significant difference (p=0.05) was observed between the conventional (disk plough and harrow) and no-tillage systems. Three times hand weeding of maize gave a marginal non-significant (p=0.05) gain over weeding once. Gesparim-ombbi 500 FW at a rate of 3.5 kg a.i. ha⁻¹ maintained a weed-free crop throughout the season. Moreover, it was reasonably less costly providing a good opportunity for weed control on maize in this labour problem region.

Introduction

A prime objective of tillage is weed control (Triplett and Van doren 1977). Satisfactory weed control in no-tillage (NT) is generally achieved by timely application of herbicides (Triplett and Van Doren 1977, Morrison et al 1990). Phillips and Young (1973), Morrison et al (1990), Triplett and Van Doren (1977), Aina (1979), and Baeumer and Bakermans (1973) stated the merits of NT over conventional tillage (CT) for the former conserves soil and water, saves labour and energy, helps in proper timing of operations, and above all is economical. The growth and yield response of maize to tillage methods is differential depending on the type of soil-water regime on which it is grown. On a well-drained soil, crop yields were higher with NT than with CT (Miller and Aarstad 1990, Dick et al 1991). The difference in plant population, however, was not significant (Miller and Aarstad 1990). On a silt loam, grain yield differences between CT and NT were not significant (Graven and Carter 1990, Barnett 1990). Mature plant height was greater under no-till (Graven and Carter 1990). Mature plant height (Barnett 1990) and emergence (Graven and Carter 1990, and Barnett 1990) were not consistent. Final stand was not significantly different (Graven and Carter 1990, and Barnett 1990). On poorly drained soils, NT yielded consistently lower than CT (Griffith et al 1988, Dicket et al 1991).
In a study by IITA (1981), weed control methods influenced the response of maize yield to tillage practices. CT, reduced tillage and NT gave identical crop yield when hand weeded, but CT was significantly superior to NT when a pre-emergence herbicide was used.

In Abobo area, since the beginning of the settlement program in 1985, the indigenous farmers’ practice-cut-burn-plant system of land preparation for maize is being replaced by mechanical tillage - disk ploughing and covering seeds using disk harrow. Weeds often grow on already plowed land requiring one or more additional harrowing before planting. This operation, in years of heavy rainfall, is thwarted by wet soil conditions leading to late planting or fallowing. Baeumer and Bakermans (1973) stress the need for replacing CT, for among other reasons, when timing of tillage operation is difficult. In the area, weeds in maize are not adequately controlled, for labour is constrained due to overlapping of maize weeding with other farm operations, and labour inefficiency due to malaria and adverse weather conditions. In the absence of previous recommendation, therefore, sound weed control practice that goes well with the tillage options deserves to be looked into. Therefore, the objectives of this experiment were to study the growth and yield response of maize to various tillage methods and to compare a promising herbicide and different hand weeding regimes for weed control, maize yield and economic efficiency of weeding maize.

Materials and Methods

A tillage and weed control experiment was conducted using a split plot design in 1988 and 1989 cropping seasons at Abobo Research Center. Five tillage and five weed control methods were placed in the main plots and sub-plots respectively. The same site but different experimental fields were used in 1988 and 1989. Maize was the preceding crop in both years. Crop residue was removed in 1988 and burnt off in 1989 (farmers practice). Three replications were used. Ploughing was done in March using a tractor mounted disk plough and harrowing using a tractor mounted disk harrow. The depth of ploughing and harrowing were 30 cm and 12 cm, respectively. A maize variety AboBako was planted at a spacing of 75 cm between rows and 20 cm between plants. Glyphosate was sprayed a week before planting and Gesaprim-Combi 500 FW in a volume of 250 l ha⁻¹ applied as pre-emergence using a CP-3 knapsack sprayer. Details of the treatments are presented in Table 1. Weeds were either hand pulled or hoed as per requirement of the respective treatments. Observation on weeds was done during 15-20 days after crop emergence and at crop maturity. Total weed plants falling in 0.25 m² quadrat placed randomly at two spots in each sub plot were used to determine weed frequency and density. These in turn served to determine relative density (RD) and relative frequency (RF) of each weed species for each treatment and for the experiment as a whole.
RD = Number of plants of a species \times 100 \\
Number of plants of all species

RF = \frac{\text{Frequency of a species}}{\text{Total frequency of all species}} \times 100

\text{Importance Value (IV) = RD+RF}

Weeds were harvested above ground from the same size quadrat in each plot for determination of weed fresh weight at crop maturity. Maize was harvested in late August and mid-to late-September for late April and May plantings, respectively. Data on crop performance include grain yield, plant height and plant stand at harvest. Weed and crop data were recorded from the central five rows. At each hoeing and weeding, the labour consumed per plot was recorded. For determining the cost of operation for each tillage and/or weeding treatment: Gesaprim-combi 500 FW was valued at FW 9 L\(^{-1}\), glyphosate at Birr 47 L\(^{-1}\), cost of chemical application at Birr 10 ha\(^{-1}\), ploughing service at Birr 108 ha\(^{-1}\), harrowing service at Birr 28 ha\(^{-1}\) and wage rate at Birr 3.25 workday\(^{-1}\).

Table 1. Details of the tillage and weed control treatments.

<table>
<thead>
<tr>
<th>A. Tillage (Main plot)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Plough + harrow + plant in late April (PHA)</td>
</tr>
<tr>
<td>2. Plough + harrow + plant in May (PHM)</td>
</tr>
<tr>
<td>3. Harrow + plant in May (HM)</td>
</tr>
<tr>
<td>4. Plough + glyphosate + plant in May (PGM)</td>
</tr>
<tr>
<td>5. Glyphosate 1 kg a.i. ha(^{-1}) + plant in May (GM)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B. Weed Control (Sub-plot)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Hand pulling 25-30 DACE(^{1}) (HP(_{2}))</td>
</tr>
<tr>
<td>2. Hand pulling 15-20 and 35-40 DACE (HP(_{1}))</td>
</tr>
<tr>
<td>3. Hand pulling 15-20, 35-40 and 55-60 DACE (HP(_{3}))</td>
</tr>
<tr>
<td>4. Hoeing 15-20 and hand pulling 35-40 and 55-60 DACE (HP(_{4}))</td>
</tr>
<tr>
<td>5. Gesaprim-Combi 500 FW at 3.5 kg a.i. ha(^{-1}) pre-emergence and hand pulling 35-40 DACE (GCH)</td>
</tr>
</tbody>
</table>

\(^{1}\) DACE = Days after crop emergence

Results

Crop performance:

The difference in harvest densities was significant (P = 0.05) in 1989 only (Table 3). However, a consistently lower plant population was observed from no-till plots in both years. Harvest densities were not significantly different for the various weeding treatments imposed.
Unlike the results of Graven and Carter (1990), mature plant height differences due to tillage treatments were non-significant. Neither were for weeding treatments.

Higher grain yield was obtained in 1988 than in 1989 (Table 2). The conventional tillage system (PHM) yielded higher than the reduced or no-till system. The intermediate tillage intensities, ploughing (PGM) and disk harrowing (HM) yielded in between the conventional and no-tillage system, with HM producing on the average better than PGM. No-till plots yielded the least in both years. But combined analysis didn't detect a significant difference due to the tillage treatments. Particularly in 1989, grain yield had a strong positive correlation with plant population for May plantings.

Table 2. Tillage and weed control effects on growth and grain yield of maize.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Number of Plants (m²)</th>
<th>Plant height (cm)</th>
<th>Grain yield (kg ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tillage (T)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHA</td>
<td>4.7 6.0 5.4</td>
<td>233 226 230</td>
<td>7630 4670 6150</td>
</tr>
<tr>
<td>PHM</td>
<td>4.7 5.7 5.2</td>
<td>270 252 261</td>
<td>7350 5710 6530</td>
</tr>
<tr>
<td>HM</td>
<td>4.8 5.4 5.1</td>
<td>268 250 259</td>
<td>7010 5270 6140</td>
</tr>
<tr>
<td>PGM</td>
<td>4.8 5.0 4.9</td>
<td>267 243 255</td>
<td>7270 4840 6050</td>
</tr>
<tr>
<td>GM</td>
<td>4.2 4.3 4.3</td>
<td>266 247 257</td>
<td>6800 4510 5650</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>NS 0.6 -</td>
<td>NS 15 -</td>
<td>NS 810 NS</td>
</tr>
<tr>
<td>CV(%)</td>
<td>- - -</td>
<td>- - -</td>
<td>17 21.3 19.1</td>
</tr>
<tr>
<td>Weed Control (W)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HP₂</td>
<td>4.6 5.3 5.0</td>
<td>258 247 252</td>
<td>6840 4910 5870</td>
</tr>
<tr>
<td>PH₂</td>
<td>4.6 5.3 5.0</td>
<td>257 243 250</td>
<td>7170 4950 6060</td>
</tr>
<tr>
<td>HP₀</td>
<td>4.7 5.2 5.0</td>
<td>264 240 252</td>
<td>7460 5230 6340</td>
</tr>
<tr>
<td>HoHP₂</td>
<td>4.7 5.4 5.1</td>
<td>261 242 251</td>
<td>7330 4960 6150</td>
</tr>
<tr>
<td>GCH</td>
<td>4.5 5.3 4.9</td>
<td>264 245 254</td>
<td>7260 4950 6100</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>NS NS -</td>
<td>NS NS -</td>
<td>NS NS NS</td>
</tr>
<tr>
<td>CV(%)</td>
<td>- - -</td>
<td>- - -</td>
<td>12.5 18.2 14.8</td>
</tr>
<tr>
<td>TxW</td>
<td>NS NS -</td>
<td>NS NS -</td>
<td>NS NS NS</td>
</tr>
</tbody>
</table>

Table 5 presents costs and ease of operation of the tillage methods. April planting using CT (PHA) costed more than NT(GM) or reduced tillage (HM) but was less expensive than PGM. Reduced tillage (HM) is by far the least costly and gave statistically comparable yields to CT (PHM).

There was no significant yield difference due to weed control treatments in both years. Three times hand pulling of weeds - the best yielding weed control treatment yielded on the average 470 kg ha⁻¹ grain over one time hand pulling - the least yielding treatment (Tables 2 and 4). The HoHP₂ treatment while producing similar yield, absorbed the highest labor and was the most expensive treatment. Plots treated with Gesaprim-Combi 500 FW at 3.5 kg a.i. ha⁻¹ pre-emergence best controlled weeds requiring only three mandays ha⁻¹ for supplementary
handweeding. It came second only to once hand pulling in cost effectiveness (Table 4). The interaction between tillage and weed control methods was not significant.

Table 3. Evaluation of operation costs and ease of operation of the tillage methods.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost (Birr ha(^{-1}))</th>
<th>Ease of operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHA</td>
<td>136</td>
<td>Ploughing and harrowing are done in time before the onset of wet soil conditions, weeds are not problematic at planting and, therefore, is simple.</td>
</tr>
<tr>
<td>PHM</td>
<td>136</td>
<td>Heavy weed growth may entail additional harrowing and wet soil conditions may thwart harrowing operation.</td>
</tr>
<tr>
<td>PGM</td>
<td>212</td>
<td>This is theoretically simple, but poor control of pre-planting weeds by glyphosate enhanced weed interference with seed placement and exposed the seedings to early competition with weeds.</td>
</tr>
<tr>
<td>HM</td>
<td>28</td>
<td>Weeds grow tall, clog the disk harrow and reduce the efficiency of harrowing. Wet soil conditions may also not allow machinery into the field for harrowing. As in PHM more than a single pass could be needed.</td>
</tr>
<tr>
<td>GM</td>
<td>104</td>
<td>As in number 3 above.</td>
</tr>
</tbody>
</table>

Table 4. Effect of weed control methods on weed growth and economics of weeding maize.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Weed fresh weight ((g m^{-2}))</th>
<th>Number of weeds ((m^{-2}))</th>
<th>Number of mandays (ha^{-1})</th>
<th>Cost of weeding ((Birr ha^{-1}))</th>
<th>Grain yield ((kg ha^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1988</td>
<td>1989 mean</td>
<td>1988 mean</td>
<td>1989 mean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HP,</td>
<td>1294°</td>
<td>944°</td>
<td>1119</td>
<td>40°</td>
<td>26°</td>
</tr>
<tr>
<td>HP,</td>
<td>458°</td>
<td>728°</td>
<td>593</td>
<td>65°</td>
<td>18°</td>
</tr>
<tr>
<td>HP,</td>
<td>430°</td>
<td>335°</td>
<td>393</td>
<td>57°</td>
<td>16°</td>
</tr>
<tr>
<td>HoHP,</td>
<td>542°</td>
<td>194°</td>
<td>368</td>
<td>62°</td>
<td>23°</td>
</tr>
<tr>
<td>GCH</td>
<td>82°</td>
<td>364°</td>
<td>223</td>
<td>32°</td>
<td>5°</td>
</tr>
<tr>
<td>CV(%)</td>
<td>47.5</td>
<td>13.8</td>
<td>-</td>
<td>30.8</td>
<td>50.8</td>
</tr>
</tbody>
</table>

* Means followed by the same letter within the column are not significantly different from each other at 5% level using DMRT. ** Data for weed fresh weight and number of weeds were detransformed from log and square root transformation, respectively.
Weed Growth

There was a considerably more weed growth in PGM and GM main plots at early crop growth stage when compared with plots that received mechanical tillage towards planting (Data not shown). A significant weed fresh weight and weed count differences were observed due to weeding treatments. Weed fresh weight was highest when plots received HP, and lowest when treated with Gesaprim-Combi (GCH). Total weed population was by far the least in GCH as well. (Table 4).

The major weed species recorded and their relative abundance at 25 days after crop emergence and at crop maturity are given in Table 5. *Corchorus olitersus* and *Boerhaavia erecta* are weeds of early crop growth stages. On the contrary, *Parthenium* sp appeared late in the season and was the most abundant one. *Commelina* sp, *Setaria* sp. and *Celosia trygina* prevailed through out the crop growth.

Discussion

Lower yield in 1989 than 1988 may largely be due to the lower amount of rainfall received in July for 1989 than for 1988.

Harvest densities were lower for no-tillage than for reduced or conventional tillage. Unlike our findings, Miller and Aarstad (1990), Graven and Carter (1990) and Barnett (1990) reported a non-significant difference in final stand between the conventional and no-till system. Phillips and Young (1973) noted an occasionally more favourable conditions for firm seed-soil contact that promotes rapid seedling emergence and growth in conventional seedbeds than no-tillage plantings. We as well noted that glyphosate at 1.0 kg a.i. ha⁻¹ poorly controlled some weeds notably *Corchorus olitersus* and *Commelina* sp, physically hindering seed placement and therefore, rendering the seeds for poor contact with the soil. As a result, we observed an initial poor emergence in no-till plots which later was complicated with the damage by field rats on emerging seeds and seedlings. Phillips and Young (1973) also suggested the possibility of such losses due to field mice, moles and other rodents in no-tillage fields than in conventional tillage fields. Deibert (1989) reported similar plant losses with reduced tillage due to rabbit damage after plant emergence on sunflower. In our case, experience in this area indicate more elasticity in plant population without a significant change in yield. Hence, it is unlikely that only variation in plant population caused such a difference in yield particularly in 1989.

Plants at maturity were shortest for PHA treatment in both years with significant difference in 1989 (Table 2). However, this, when compared to the same soil manipulation but with May planting (PHM treatment) is largely due to sowing time effect.

The costs incurred and the difficulties faced in implementing the various tillage
treatments are summarized in Table 5. In PHA treatment, the operation was simple and the seed bed was fine, but in practice maize area planted as early as this time is very small because of, inter alia, shortage of labour and machinery. Moreover, the crop matures earlier than the main season rain subsides lending the crop to greater post harvest losses due to germination and rotting. The observed and/or anticipated problems with HM were heavy weed burden at harrowing that interfered with the operation, and soil compaction or total failure of harrowing operation when the soil is wet. Hence for this treatment to be valid, weeds should reasonably be short and the soil not too wet. NT (GM) would be ideal if good pre-planting weed control was attained by glyphosate. Despite this, of all tillage treatments, GM is the most compatible with the farming system - it avoids the total dependent on machinery for land preparation. The fact that it yielded the least in this study, therefore, may not preclude the further evaluation and possible use of it as an alternative to CT. The PGM treatment did not show any merit over either the conventional or NT systems. In fact it was the most expensive of all the tillage treatments.

The yield difference between once and thrice weeding was neither agronomically significant nor economically attractive. It is, therefore, likely that one early weed control is sufficient for reasonable yield of maize. The control method, whether cultural or chemical, should focus on the dominant weeds of early crop stage *Corchorus olitorius*, *Celosia trygina*, *Boerhavia erecta* and *Commelina* sp.

### Table 5. Relative abundance of some of the major weed species in the experimental sites (1988-1989).

<table>
<thead>
<tr>
<th>Weed species</th>
<th>25 DACE</th>
<th>At crop maturity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RD</td>
<td>RF</td>
</tr>
<tr>
<td><em>Commelina</em> sp.</td>
<td>9.7</td>
<td>15.2</td>
</tr>
<tr>
<td><em>Celosia trygina</em></td>
<td>21.9</td>
<td>18.2</td>
</tr>
<tr>
<td><em>Corchorus olitorius</em></td>
<td>27.5</td>
<td>22.6</td>
</tr>
<tr>
<td><em>Boerhavia erecta</em></td>
<td>16.5</td>
<td>15.6</td>
</tr>
<tr>
<td><em>Setaria</em> sp.</td>
<td>5.9</td>
<td>6.5</td>
</tr>
<tr>
<td><em>Parthenium</em> sp.</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Others</td>
<td>18.5</td>
<td>21.9</td>
</tr>
</tbody>
</table>

Conclusion

A first hand attempt was made to explore the possibility of introducing minimum or zero tillage primarily as a strategy to reduce the need for mechanical tillage. In Abobo red soil area tillage can either be reduced as far as pre-planting weeds
are adequately controlled by light harrowing or even totally avoided if so far as these weeds are controlled by herbicides, without significantly affecting maize grain yield.

Post-crop emergence weed control by herbicides seemed to fit well into the system as it reduced labour requirement for maize weeding. Hoeing appeared to be not important in enhancing maize growth and yield. Though not significant, a consistent yield gain was observed in going from one to three times hand weeding.

As a follow-up work it is suggested that rate and time of application of glyphosate as well as other non-selective herbicides be evaluated for NT seedbed preparation. Emphasis could be given to soil acting herbicides so that the seedbed is kept free of weeds until planting time. There is a need to study tillage-associated changes in soil properties as well.

References

Effect of crop rotation on weed control and grain yield of maize

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Abstract

The effect of crop rotation on weed control and grain yield of maize was studied for four years on loam soils of Awasa, southern region of Ethiopia. The treatments comprised four crops (maize, tef, soyabean and sunflower) and two levels of fertilizer (unfertilized and recommended rate for each crop). Simple correlation analysis under fertilized condition showed that there was no significant association between total weed density and maize yield. Rotating crops from year to year has significantly affected maize grain yield. The monocrop gave the lowest yield. The best crop sequence for maize was found to be sunflower, soyabean and tef which had a yield advantage of 41% over the monocrop.

Introduction

Weeds are a major obstacle in maize production and reduce crop yield if not controlled on time. They consume labor, time and cost. Over-lapping of activities, labor shortage and continuous rain during weeding time force farmers to weed their crop late. Weed competition studies on maize, sunflower, soyabean, haricot bean and sweet potato indicated that full season weed competition causes yield reductions up to 59%, 57%, 95%, 94% and 99%, respectively. In these studies late weeding had always higher cost and decreased yield (45).

Survey informations in Arsi Negelle area (3) showed the requirement of high number of mandays ha⁻¹ to weed maize, tef, and wheat. Labor shortage is reported to exist both at Arsi Negelle and Sidama awraja (2, 3). According to farmers of Wolayita awraja rotation of maize, tef, haricot bean and sweet potato showed a suppressing effect on weed infestation (1). Thus, maize grown after tef, haricot bean or sweet potato gave better yield.

Farmers in the surveyed areas are in short of cash and farm inputs to intensify crop production. Where there is shortage of agricultural in-puts like (Pesticides or fertilizers) and very limited capital as well as labor and time shortage, the practice of crop rotation is of vital importance. Rotation can reduce
weed density, increase the fertility of the land, give broader labor distribution and income diversification and the soil nutrients can efficiently be used by the different crops grown.

The objectives of this study were to examine the impact of crop rotation on weed control and crop yield; and to determine the appropriate crop sequence in maize production.

Materials and Methods

This experiment was carried out at Awasa Research Center during 1987-1990 on loamy soil with pH of 6.2. The experiment design was a split plot design in three replications. The main plots were fertilizer levels: unfertilized Vs fertilized - (recommended rate for each crop). The sub-plots consisted of four crop varieties: maize (A511), tef (DZ-01-354), Soyabean (Davis) and sunflower (cher. X-gene pool 11) with their combinations. Details of the treatments are shown in Table 1. Soil samples were randomly taken before planting for NPK, OC, and pH analysis from 0-30 cm depth. Main plot size was 10m x 33m with a sub-plot of 10m x 7.5m. Data on weed count, visual weed control score and grain yield were recorded and subjected to analysis of variance and the means separated by LSD or DMRT at 5% level of probability.

Results and Discussion

Weed control: Major weeds of the experimental site were: Nicandra physalodes, Galinsoga parviflora, Tagetes minuta, Portulaca oleracea, commelina benghalensis, Amaranthus hybridus, Brassica sp. Digitaria sp., Setaria sp and Eragrostis sp. Density of the most frequent weed species for the various crop sequence combinations is shown in Table 1. There was no significant differences (p = 0.05) in density levels of weed species between crop sequence treatments regardless the rate of fertilizations. Eventhough not at significant level lower population for all weeds species was observed from crop sequence (tef, soyabean, sunflower and maize).

Simple correlation analysis under fertilized condition showed that there was no significant association between total weed density and maize yield (Table 2). However, there was a decrease in grain yield with increasing weed density in some of the sequences.

Grain yield: significant yield difference was observed among crop sequences. The highest maize yield was obtained from the crop sequence of sunflower, soyabean, tef and maize which gave 48% higher yield over the monocrop (Table 3). The monocrop maize and the sequence of maize, tef and maize gave the lowest mean grain yield. Maize yield was reduced by 12% in the crop sequence of maize, tef and maize compared to the sole maize sequence. It seemed that continuous
Table 1. Density of different weed species for the various crop sequence combinations.

<table>
<thead>
<tr>
<th>Crop sequence*</th>
<th>Total</th>
<th>Nicandra</th>
<th>Physalodes</th>
<th>Galinsoga</th>
<th>Parviflora</th>
<th>Tagetes</th>
<th>minuta</th>
<th>Eragrostis</th>
<th>sp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>T.Sb.Sf.m</td>
<td>97.6</td>
<td>46.4</td>
<td>9.6</td>
<td>1.6</td>
<td>40.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T.Sf.Sb.m</td>
<td>139.2</td>
<td>81.6</td>
<td>14.4</td>
<td>9.6</td>
<td>33.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sb.Tsf.m</td>
<td>155.2</td>
<td>59.2</td>
<td>38.4</td>
<td>8.0</td>
<td>49.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sb.Sf.T.m</td>
<td>172.8</td>
<td>75.2</td>
<td>11.2</td>
<td>3.2</td>
<td>83.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sf.Tsb.m</td>
<td>108.8</td>
<td>43.2</td>
<td>0.0</td>
<td>9.6</td>
<td>56.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sf.Sb.T.m</td>
<td>209.6</td>
<td>142.4</td>
<td>3.2</td>
<td>8.0</td>
<td>56.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>m.Sb.T.m</td>
<td>187.2</td>
<td>137.6</td>
<td>0.0</td>
<td>4.8</td>
<td>44.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T.Sb.m.m</td>
<td>208.0</td>
<td>161.6</td>
<td>4.8</td>
<td>8.0</td>
<td>33.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>m.T.m.m</td>
<td>236.8</td>
<td>174.4</td>
<td>20.8</td>
<td>3.2</td>
<td>38.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sb.T.T.m</td>
<td>201.6</td>
<td>75.2</td>
<td>17.6</td>
<td>1.6</td>
<td>107.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>m.Sb.T.m</td>
<td>244.8</td>
<td>185.6</td>
<td>8.0</td>
<td>8.0</td>
<td>43.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>m.m.m.m</td>
<td>161.6</td>
<td>94.4</td>
<td>14.4</td>
<td>12.8</td>
<td>40.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>176.9</td>
<td>106.4</td>
<td>11.9</td>
<td>6.5</td>
<td>52.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ground cover %</td>
<td>100.0</td>
<td>60.1</td>
<td>6.7</td>
<td>3.7</td>
<td>29.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>NS</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Sb - soybean
Sf - Sunflower
m - maize
T - tef

Table 2. Simple correlation analysis indicating some relationship between maize yield and total weed density under fertilized condition.

<table>
<thead>
<tr>
<th>Crop Sequence*</th>
<th>Weeds (m²)</th>
<th>Maize grain yield (kg ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T.Sb.Sf.m</td>
<td>78.4</td>
<td>4067</td>
</tr>
<tr>
<td>Sf.Sb.T.m</td>
<td>91.2</td>
<td>4780</td>
</tr>
<tr>
<td>T.Sb.m.m</td>
<td>107.2</td>
<td>3600</td>
</tr>
<tr>
<td>Sf.T.Sb.m</td>
<td>116.8</td>
<td>3640</td>
</tr>
<tr>
<td>T.Sf.Sb.m</td>
<td>118.4</td>
<td>4247</td>
</tr>
<tr>
<td>Sb.T.m.m</td>
<td>123.2</td>
<td>3733</td>
</tr>
<tr>
<td>m.T.m.m</td>
<td>126.4</td>
<td>3400</td>
</tr>
<tr>
<td>Sb.St.T.m</td>
<td>132.8</td>
<td>4647</td>
</tr>
<tr>
<td>Sb.T.T.m</td>
<td>137.6</td>
<td>4220</td>
</tr>
<tr>
<td>m.m.m.m</td>
<td>145.6</td>
<td>3460</td>
</tr>
<tr>
<td>Sb.T.Sf.m</td>
<td>169.6</td>
<td>3440</td>
</tr>
<tr>
<td>m.Sb.m.m</td>
<td>180.8</td>
<td>3293</td>
</tr>
<tr>
<td>r = -0.5288</td>
<td>NS</td>
<td></td>
</tr>
</tbody>
</table>

* Treatment details given in Table 1.
growing of cereals gives lower grain yield. Better yield was obtained when maize was grown in the rotation that includes sunflower, soyabean and tef. This indicates that under unfertilized condition the use of crop rotation with the inclusion of soybean, tef and sunflower can be the best alternative for the state farms or peasant farm sectors.

No significant grain yield differences were found from any crop sequence combinations when fertilizer was applied. However, the highest yield was obtained when maize is grown in the crop sequence that includes sunflower, soybean and tef. There was a respective yield increment of 38% and 34% from (sunflower, soybean, tef, maize) and (soybean, sunflower, tef, maize) crop sequence combinations (Table 4). In some of the crop sequences there is less response to fertilizer application (Table 3). On the other hand, there is a need to apply fertilizer to those crop sequences with high response (better yield increase over the unfertilized).

Crop rotation has significantly affected the grain yield of maize. The sequences (M.T.M.M and M.M.M.M) gave the lowest yield. The results shows that crop rotation has a yield advantage of 17% over monocrop. In addition, shift in weed species and reduction in weed population was observed under crop rotation. Those sequences with continuous cereals (M.T.M.M, Sb.T.T.M and M.M.M.M) had higher yield response to fertilizer application. This could be due to the depletion of soil nutrients by the preceding crops. This implies that for a better crop yield under continuous monocropping of cereals there is a need to apply fertilizer.

**Conclusion**

Based on the result of this study the following inferences were made. Shift in weed types was observed during the seasons of the study. Weed density of various weed types was reduced. Though not significant, there was some indication of correlation in some of the sequences between weed density and grain yield under fertilized condition. Under unfertilized condition, crop rotation was found to be useful - it gave a yield advantage of 22% over the monocrop; crop rotation under fertilized condition had less yield benefit (13.2%) as compared to monocrop - but the advantage of rotation in this situation was reduction in weed density. In monocrop, fertilizer application increased the yield by 33% and grain yield was not significantly different between fertilizer levels.
Table 3. Mean grain yield of maize under fertilized and unfertilized conditions during the four years crop rotation.

<table>
<thead>
<tr>
<th>Crop sequence</th>
<th>Unfertilized (F₀)</th>
<th>Fertilized (F₁)</th>
<th>Mean</th>
<th>% Yield increase of F₁ over F₀</th>
</tr>
</thead>
<tbody>
<tr>
<td>T.Sb.Sf.m</td>
<td>3567(40)</td>
<td>4067(18)</td>
<td>3817(27)abc</td>
<td>14.0</td>
</tr>
<tr>
<td>T.Sf.Sb.m</td>
<td>3767(48)</td>
<td>4247(23)</td>
<td>4007(33)ab</td>
<td>12.7</td>
</tr>
<tr>
<td>Sb.T.Sf.m</td>
<td>2987(17)</td>
<td>3440(-1)</td>
<td>3214(7)bcd</td>
<td>15.2</td>
</tr>
<tr>
<td>Sb.Sf.T.m</td>
<td>3413(34)</td>
<td>3647(34)</td>
<td>4030(34)ab</td>
<td>36.2</td>
</tr>
<tr>
<td>Sf.T.Sb.m</td>
<td>3087(21)</td>
<td>3640(5)</td>
<td>3364(12)bcd</td>
<td>17.9</td>
</tr>
<tr>
<td>Sf.Sf.T.m</td>
<td>3700(45)</td>
<td>4780(38)</td>
<td>4240(41)a</td>
<td>29.2</td>
</tr>
<tr>
<td>m.Sb.T.m</td>
<td>3260(28)</td>
<td>3733(8)</td>
<td>3497(16)abcd</td>
<td>14.5</td>
</tr>
<tr>
<td>T.Sb.m.m</td>
<td>2640(3)</td>
<td>3600(4)</td>
<td>3120(4)cd</td>
<td>36.4</td>
</tr>
<tr>
<td>m.T.m.m</td>
<td>2240(-12)</td>
<td>3400(-2)</td>
<td>2820(-6)d</td>
<td>51.8</td>
</tr>
<tr>
<td>Sb.T.T.m</td>
<td>2713(6)</td>
<td>4220(22)</td>
<td>3467(22)abcd</td>
<td>55.5</td>
</tr>
<tr>
<td>m.Sb.m.m</td>
<td>2753(-5)</td>
<td>3293(-5)</td>
<td>3023(1)cd</td>
<td>19.6</td>
</tr>
<tr>
<td>m.m.m.m</td>
<td>2553(0.0)</td>
<td>3460(0.0)</td>
<td>3007(0.0)d</td>
<td>35.5</td>
</tr>
<tr>
<td>Mean</td>
<td>3057</td>
<td>3877</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD%</td>
<td>927</td>
<td>NS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SE±</td>
<td>320</td>
<td>387</td>
<td>253</td>
<td></td>
</tr>
<tr>
<td>CV(%)</td>
<td>21</td>
<td>19</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

* Treatment details given in Table 1.
** Means followed by similir letters within a column are not significantly different at (P=0.05) according DMRT.
*** Numbers in parenthesis are percent increase or decrease over monocrop.

References

On-station verification of herbicides on maize in Awasa

Yeshi Chiche
Institute of Agricultural Research
P.O.Box 2003, Addis Ababa

Abstract

On-station field experiments were conducted in Awasa Research Center, southern region of Ethiopia in 1984-1988 to verify economic feasibility of Gesaprim 500 FW (atrazine) and Primextra 500 FW (atrazine + metolachlor 1.7:3.3) over the standard herbicide treatment Primagram 500 FW (atrazine + metolachlor 1:1) and the twice hand weeded check treatment. Average grain yield from atrazine or hand weeding treatment were significantly (P=0.05) higher compared to the atrazine + metolachlor treated plots. Results from these experiments showed that atrazine gave higher maize yield, higher net benefit and lower operating ratio than the rest herbicide or hand needed treatments. Hence, it was concluded atrazine at 2.0 kg a.i. ha⁻¹ can replace hand weeding or atrazine + metolachlor 1:1 without any economic loss for this specific location where broad leaf species are a dominant weed problem. But, further verification of the existing herbicide recommendations is desirable for the management of broadleaf and grass weed species in representative maize growing areas of the region.

Introduction

Weeds are a serious problems in the peasant and state farm sector on maize in southern region of Ethiopia. Maize/weed competition investigation conducted at Awasa Research Center indicated that yield loss due to uncontrolled weed growth reaches up to 47%. An average yield loss of 59% due to weed competition was also reported from maize growing areas of the southern region (1).

Weed control in the peasant sector is entirely depending on cultural and labor intensive practices. Maize fields are weeded once or twice at one month interval after germination using hoe. About half of the farmers practice two hand weeding. Where available, one oxen cultivation, locally called 'shilshallo' follow the first hoeing (2).

Herbicides are essential components of maize production in the state farm sector. In the state farms neither hand weeding nor crop rotation is simple to practice. Weeds, therefore are controlled mainly by herbicides; the most common
herbicide are Primagram 500 FW (atrazine + metolachlor 1:1). Several pre-emergence herbicides have been recommended for use in maize by the weed science section of Awasa Research Center. But none of these herbicide recommendations were verified in a large scale situations. The objective of the present study was to verify the comparative advantage and economic acceptance of Primagram over Gesaprim 500 FW (atrazinc), Primextra 500 FW (atrazine + metolachlor 1.7:3.3 and the recommended hand weeding practice.

Materials and Methods

The study was carried out on seed production fields of Awasa Research Center for four years (1984, 1986, 1987 and 1988). The trials were laid out on non-replicated larger plots of different fields every year and fields were selected based on their uniformity to the existing weed flora of the trial sites. Plot size varied from 0.25 ha to 1.0 ha (based on land availability). Maize variety used was Awasa-511. Plots were fertilized with urea (kg ha⁻¹) at a knee height stage of the crop. In herbicide treated plots the fertilizer was incorporated by gentle disturbance of the soil without touching the weeds. For the hand weeding treatment the fertilizer was applied during the second weeding operation. The experimental variables were application of herbicides, weeding, harvesting and shelling. All other cultural practices such as land preparation, planting date, seed rate and fertilizer rate were constant (non-experimental variables). The treatments comprised: Gesaprim 500 FW (atrazinc) 2.0 kg a.i. ha⁻¹, Primextra 500 FW (atrazine + metolachlor 1.7:3.3) 2.0 kg a.i. ha⁻¹, Primagram 500 FW (atrazine + metolachlor 1:1) 2.0 kg a.i. ha⁻¹ and twice hand weeding. Labour hours were calculated by converting man hours to mandays at the rate of 8 hrs day⁻¹. Partial budget analysis and Marginal Rate of Return (MRR) were calculated using: Government fixed price (Birr 26 per 100 kg), State Farms selling price (Birr 31 per 100 kg) and average market price of each year.

Results and Discussion

Grain yields obtained from alternative weed control practices are shown in Table 1. Results of analysis of variance showed significant differences among treatments. Treatments effect have the same pattern in the grain yield performance of maize throughout the four experimental years. Average grain yield from atrazine or the hand weeding treatments gave significant (P<0.05) higher yield compared to the atrazine + metolachlor mixtures treated plots.

The dominant weed species of the experimental site were: Nicandra physalodes, Commelina benghalensis, Galinsoga parviflora, Amaranthus hybridus, Portulaca oleracea, Tagetes minuta, Brassica sp. and Cyperus sp. Most broadleaf
weed species were effectively controlled by atrazine. All herbicide treatments did not persist long to give adequate control of *Cyperus* sp. (data not shown). Higher

Table 1. Effect of different weed control treatments on grain yield of Maize.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>1984</th>
<th>1986</th>
<th>1987</th>
<th>1988</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yield (kg ha⁻¹)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Atrazine</td>
<td>3382</td>
<td>5458</td>
<td>5580</td>
<td>4100</td>
<td>4630</td>
</tr>
<tr>
<td>Atrazine + metolachlor (1:1)</td>
<td>3018</td>
<td>4302</td>
<td>5648</td>
<td>2780</td>
<td>3937</td>
</tr>
<tr>
<td>Atrazine + metolachlor (1.7:3.3)</td>
<td>2948</td>
<td>4182</td>
<td>5092</td>
<td>3556</td>
<td>3944</td>
</tr>
<tr>
<td>Hand weeding</td>
<td>3436</td>
<td>5548</td>
<td>6104</td>
<td>4436</td>
<td>4881</td>
</tr>
</tbody>
</table>

S.E. ± 1.27
LSD (0.05) = 5.75 kg ha⁻¹
CV% = 8.29

Table 2. Operating ratio * of weed control treatments.

<table>
<thead>
<tr>
<th></th>
<th>Government price (%)</th>
<th>State Farm price</th>
<th>Average market price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atrazine</td>
<td>14.8</td>
<td>12.44</td>
<td>7</td>
</tr>
<tr>
<td>Atrazine + metolachlor (1:1)</td>
<td>18</td>
<td>15</td>
<td>9</td>
</tr>
<tr>
<td>Atrazine + metolachlor (1.7:3.3)</td>
<td>19</td>
<td>16</td>
<td>9</td>
</tr>
<tr>
<td>Hand weeding</td>
<td>22</td>
<td>18</td>
<td>11</td>
</tr>
</tbody>
</table>

* Operating Ratio = Variable Cost X 100
Gross income

yields of the hand weeded check treatment could be due to the complete control of broadleaf weed species including *Cyperus* sp.

The total expenses saved by using herbicides over-hand weeding showed negative values, atrazine being relatively cheaper. The hand weeding treatment has higher operating ratio while atrazine has lower (Table 2).

Higher net benefit was obtained from atrazine in almost the three different prices (Table 3). It is only in 1988 that the net benefit of hand weeding slightly exceeded that of atrazine at open market price (data not shown).

<table>
<thead>
<tr>
<th></th>
<th>Atrazine</th>
<th>Atrazine + metolachlor (1:1)</th>
<th>Atrazine + metolachlor (1.7:3:3)</th>
<th>Hand weeding</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average Yield</strong></td>
<td>46.30</td>
<td>39.37</td>
<td>39.44</td>
<td>48.81</td>
</tr>
<tr>
<td><strong>Gross benefit</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>at 26 birr (100 kg)</td>
<td>1203.80</td>
<td>1023.62</td>
<td>1025.44</td>
<td>1269.06</td>
</tr>
<tr>
<td>at 31 birr (100 kg)</td>
<td>1435.30</td>
<td>1220.47</td>
<td>1222.64</td>
<td>1513.11</td>
</tr>
<tr>
<td>at 53 birr (100 kg)</td>
<td>2453.90</td>
<td>2086.81</td>
<td>2090.32</td>
<td>2586.93</td>
</tr>
<tr>
<td><strong>Total Variable Cost</strong></td>
<td>178.65</td>
<td>191.87</td>
<td>195.31</td>
<td>284.08</td>
</tr>
<tr>
<td><strong>Net benefit</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>at 26 birr (100 kg)</td>
<td>1025.15</td>
<td>831.75</td>
<td>830.13</td>
<td>984.98</td>
</tr>
<tr>
<td>at 31 birr (100 kg)</td>
<td>1256.65</td>
<td>1028.60</td>
<td>1027.33</td>
<td>1229.03</td>
</tr>
<tr>
<td>at 53 birr (100 kg)</td>
<td>2275.25</td>
<td>1894.74</td>
<td>1895.01</td>
<td>2302.85</td>
</tr>
<tr>
<td><strong>Marginal net benefit</strong></td>
<td>40.17</td>
<td>153.23</td>
<td>154.85</td>
<td></td>
</tr>
<tr>
<td>at 26 birr (100 kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>at 31 birr (100 kg)</td>
<td></td>
<td>27.62</td>
<td>201.70</td>
<td></td>
</tr>
<tr>
<td>at 53 birr (100 kg)</td>
<td></td>
<td>27.60</td>
<td>407.84</td>
<td></td>
</tr>
</tbody>
</table>

**Conclusion**

Results from this on-station verification trial demonstrated that atrazine at 2.0 kg a.i. ha⁻¹ gave higher maize yield, net benefit and lower operating ratio than atrazine + metolachlor 1:1 or atrazine + metolachlor 1.7:3.3 or the twice hand weeding treatment. Hence, it was concluded that atrazine at 2.0 kg a.i. ha⁻¹ can replace hand weeding or atrazine + metolachlor without any economic loss for this specific location or areas with similar weed problem in the region. The results also indicated that at a well managed location where grass infestation are relatively light, the application of atrazine + metolachlor for economic feasibility may be unjustified.

In maize growing southern region state farms, the problems of weed control are: labor shortage, higher cost of hand weeding and untimeliness in completing the weeding operation. These farms prefer Primagram 500 FW (atrazine + metolachlor 1:1) over Gesaprim 500 FW (atrazine) for weed control considering the former controls grassy weeds better than the latter. Therefore, there is a need to verify the existing herbicide recommendations in wider areas of the southern region, weed diversity being as a major criterion for site selection. This should be the focus of future research.
References

On-farm verification of manually operated wheel-hoe weeder for maize around Bako

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Abstract

At critical times of weeding labour and draft power are in short supply for timely and adequate weeding because of overlapping of farm operations for different crops. To alleviate this problem on-farm tests of manually operated weeder (wheel hoe) was compared with farmers’ weeding practice. Wheel hoe saved 75 hrs labour ha⁻¹ and 13 oxen-pair hrs ha⁻¹ as compared to the farmers’ weeding practice. At first hoeing both treatments controlled 85% of the weeds. However, farmers’ assessment indicated that the implement could not be fully adopted unless some modifications are made. The major ones include decreasing the weight of the wheel hoe and shortening the handle.

Introduction

Several on-station experiments indicated that weeding is a critical factor in maize production. In experiments conducted at Bako and Awasa the average yield loss of maize due to uncontrolled weed growth was 46.4% (4). In the area family labour is insufficient from June to August for timely and adequate maize weeding because of overlapping of operations for different crops (3). Thus maize grain yield is greatly reduced. Moreover, weed problem is exacerbated by environmental factors of the area such as high rainfall and favourable temperature which favour rapid and vigorous growth of weeds.

The problem of weed control had received the attention of researchers and efforts were made to alleviate the problem. Recommendations regarding the frequency and timing of hand weeding and types and rates of herbicides were made. However, none of these technologies were readily adaptable by the farmers mainly because of system incompatibility in the case of hand weeding recommendation (2) and unavailability of herbicides in the case of chemical weed control recommendation (1). The problem of weeding is very pressing and feasible solution should be made available to the farmers to improve their productivity. The weed problem also discourages farmers to use purchased inputs like fertilizer and improved seeds by lowering yields and increases the risk of not paying debts. To address this labour constraint problem the Agricultural Implements Research and
Improvement Center (AIRIC) at Melkasa Research Center has developed a hand-pushed wheel-hoe weeder. AIRIC tested the wheel-hoe at Melkasa with promising results. Weeding maize took about 41.7 man-hrs ha\(^{-1}\) as compared to 169.9 man-hrs ha\(^{-1}\) for conventional weeding (3). The objective of this experiment was to verify the wheel-hoe weeder performance for weeding maize under on-farm conditions and to test its acceptability to farmers in Bako area.

**Materials and Methods**

**On-farm Researcher-designed Trial (ORD)**

The main purpose of this trial was to obtain quantitative data which could help to evaluate the technical efficiency of the wheel-hoe weeder compared with farmers' weed control practice. The criteria for evaluating the two practices included labour and oxen power requirement, weed control efficiency and percentage of crop damage. The experiment was conducted at one site in 1989 and two sites in 1990 on farmers' fields around Bako. The number of sites were kept lower because of a shortage of wheel-hoes. The experimental design was a randomized complete block with two replications per site. Gross plot size was 187 m\(^2\) (9.35 m x 20 m) with a net plot size of 155.1 m\(^2\) (8.25 m x 18.8 m). Land preparation was from February to April and fields were plowed three times including seed covering. The crop variety used in both years was Bako composite planted during early May in rows with spacings of 40 cm between plants and 55 cm between rows. In 1989 the experiment was conducted on producer cooperative (PC) farm using PC fertilizer rate of 100 kg DAP ha\(^{-1}\). In 1990 fertilizer recommendation for individual farmers (25 kg N ha\(^{-1}\)) was used.

**On-farm farmer designed Trial (OFD)**

The primary objective of this trial was to have farmers assess the wheel-hoe weeder. Each year two farmers were given the wheel-hoe and showed how to use it, then monitored their use and assessment of it. Reasons for using this approach in testing the wheel-hoe include: to obtain better information on the fatigue factor, since the farmer would use the wheel-hoe on a large area instead of on an experimental plot; the farmer could report performance of the hoe under various conditions of soil moisture and weed types; and adoption could be ascertained by the extent to which the tool was used.
Results and Discussion

In the first year two sites were selected, but only one site was planted and harvested for ORD. The other site was planted by the farmers without the presence of researchers and following the field lay out. In the second year, two sites were planted but the data was collected and used only from one site. The other site was dropped out because the farmers practiced oxen-cultivation for both treatments without consulting the researchers. As a result the statistical tests of yield differences for different weeding practices was not conducted. However, data on labour and oxen power input, weed control efficiency and plant damages were collected and analyzed (Table 1, 2, and 3).

Maize weeding using the wheel-hoe weeder relatively saved 75 labour hrs ha\textsuperscript{-1} and 13 oxen-pair hrs ha\textsuperscript{-1} as compared to farmers weeding practice (Table 1). The labour required by the wheel hoe was 212 hrs ha\textsuperscript{-1} while the farmers practice needed 287 labour and 13 oxen-pair hrs ha\textsuperscript{-1}. At the first hoeing wheel hoe required lower labour than farmers practice. But the potential time that can be used by the implement is obviously lower since the farmers easily get fatigue because of high energy requirement of the wheel-hoe. This will decrease the area of maize field that can be weeded by wheel hoe in a day. At critical period of weed competition after the first hoeing the farmers practice (oxen-cultivation) required 13 labour hours while wheel hoe required about 48 labour hrs ha\textsuperscript{-1}. So the second use of wheel hoeing is not practical as the farmers could not cover the whole plot by this implement over a short period of time. But oxen cultivation enables the farmers to cover larger areas within short periods.

Table 1. Labour, oxen and material inputs required for different maize weeding practices (1989-1990).

<table>
<thead>
<tr>
<th>Items</th>
<th>Weeding by wheel hoe</th>
<th>Farmers' weeding practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour input (hrs ha\textsuperscript{-1})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- hoeing - first</td>
<td>96.49</td>
<td>132.36</td>
</tr>
<tr>
<td>- second</td>
<td>47.47</td>
<td>0.00</td>
</tr>
<tr>
<td>Subtotal</td>
<td>143.96</td>
<td>132.36</td>
</tr>
<tr>
<td>- cultivation</td>
<td>0.00</td>
<td>13.37</td>
</tr>
<tr>
<td>- hand pulling</td>
<td>0.00</td>
<td>76.65</td>
</tr>
<tr>
<td>- slashing</td>
<td>68.10</td>
<td>64.17</td>
</tr>
<tr>
<td>Total</td>
<td>212.06</td>
<td>286.65</td>
</tr>
<tr>
<td>Oxen-power input (hrs ha\textsuperscript{-1})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- oxen-cultivation</td>
<td>0.00</td>
<td>13.37</td>
</tr>
<tr>
<td>Material input (hrs ha\textsuperscript{-1})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- wheel hoe</td>
<td>143.96</td>
<td>0.00</td>
</tr>
</tbody>
</table>
The two weed control practices scored equal, 85%, for the first hoeing (Table 2). During the second hoeing wheel hoe controlled 87% of the weeds compared with farmers' oxen-cultivation of the 98%. Data on weed count was taken before slashing (10 weeks after planting). From this observation weed density varied considerably in which 28% higher weed plants m⁻² were recorded from the wheel hoe treated plots compared with that of farmers' weeding practice. This difference was partly because of the ineffective working depth of the wheel hoe to uproot emerging weed seedlings. Pushing the wheel hoe deeper requires higher energy. It was also observed that weeds on wheel hoe weeded plots were relatively taller than the weeds on plots weeded by the farmers practice.

It was hypothesised that the farmers weeding practice, especially, oxen-cultivation causes plant damage. In this experiment more plants were damaged by wheel hoe (1151) than by farmers weeding practice (509) (Table 3). More number of plants were damaged by wheel hoe during the second hoeing than the first hoeing. The reason was that as the plants grow higher the flexibility of wheel hoe decreases in damaging weeds and reduced the farmer's control over the wheel hoe to protect crop injury.

<table>
<thead>
<tr>
<th>Items</th>
<th>Treatments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weed count (m⁻²)</td>
<td>Weeding by wheel hoe</td>
</tr>
<tr>
<td>- before 1ˢᵗ hoeing</td>
<td>1809</td>
</tr>
<tr>
<td>- after 1ˢᵗ hoeing</td>
<td>277</td>
</tr>
<tr>
<td>weed control (%)</td>
<td>85</td>
</tr>
<tr>
<td>- before 2ⁿᵈ hoeing</td>
<td>1477</td>
</tr>
<tr>
<td>weed control (%)</td>
<td>87</td>
</tr>
<tr>
<td>- after 2ⁿᵈ hoeing</td>
<td>194</td>
</tr>
<tr>
<td>weed control (%)</td>
<td>87</td>
</tr>
<tr>
<td>- before ox-cultivation</td>
<td>--</td>
</tr>
<tr>
<td>- after ox-cultivation</td>
<td>--</td>
</tr>
<tr>
<td>weed control (%)</td>
<td>--</td>
</tr>
<tr>
<td>- before hand pulling</td>
<td>--</td>
</tr>
<tr>
<td>- after hand pulling</td>
<td>--</td>
</tr>
<tr>
<td>weed control (%)</td>
<td>--</td>
</tr>
</tbody>
</table>

Table 2. Weed control efficiency of different maize weeding practices
Farmers' assessment for both weeding practices indicated that the wheel hoe is useful and can be used under the following conditions: fields with light and red soils having sufficient moisture (not too wet or too dry), finely prepared seedbeds, broadleaved weeds, less weed population, dwarf weeds and free of stones. Under heavy and muddy soil types, poorly prepared seed beds, grassy weed types, high weed density and longer weeds condition the wheel hoe could not be useful because of high energy requirement to operate it and ineffective removal of weeds under those conditions.

The farmers stressed the fact that even though the wheel hoe is useful under certain conditions still it is very heavy and requires high energy to operate and makes them fatigue more quickly. They said that wheel hoe lacks flexibility in removing weeds between plants in the row. Farmers also mentioned that the wheel hoe cannot easily be operated by women and children because of high energy requirement.

Farmers' suggestions to improve the performance of the wheel hoe under their conditions include: decrease the weight of wheel hoe and the length of the handle, forking the blade, and narrowing its width so that there is good flexibility of wheel hoe in removing weeds between plants within the same row, and increase the size of wheel to withstand the force of clods.

**Conclusion and Recommendation**

It was found out that the wheel hoe could be useful under certain conditions. But farmers' assessment indicated that the implement could not be fully adopted unless some modifications are made. Necessary feedbacks were collected from the farmers which could help the concerned researchers to modify or develop new weeding implements. Most important changes required by the farmers are: decrease the weight of wheel hoe, shorten the length of the handle, forking the blade and narrowing its width and increasing the size of the wheel.
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