Weed management in Ethiopia
an extension and training manual

Food and Agriculture Organization of the United Nations
Weed management in Ethiopia
an extension and training manual

prepared by
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Introduction

This extension manual was produced as one of the outputs of the FAO sponsored TCP/ETH/4532 Weed Management Project implemented in the Crop Protection and Regulatory Department, Ministry of Agriculture. The original need for the publication was identified by an FAO consultancy in 1984. Information for extension workers, particularly on weeds within the subject of crop protection, was severely deficient.

This manual has been produced with several objectives in mind.

■ First, it offers some general background on the concepts of weed management, presented as general principles and approaches which are used in various combinations around the world to control weeds.

■ Second, general information concerning herbicides is given. Although herbicides are hardly used in Ethiopia at the present time, they may in the future be given greater emphasis. The information provided should be useful as background for extension workers.

■ Third, as Ethiopia is an extremely varied country, both geographically and culturally, it is difficult to make generalizations concerning the weed problems, their causes, and potential solutions. A section on methods used for problem identification and choosing solutions was included to assist the extension agent in the analysis of his or her own area. Extension methodology is also covered.

■ Fourth, weed control recommendations are presented for each crop and particularly severe weeds. These recommendations are derived from the Institute of Agricultural Research findings as well as experience of the Agricultural Development Department. They are general recommendations and will need to be modified as the situation dictates.

This book is a compilation of information from various sources. The information has been chosen and organized in such a way as to hopefully benefit the upper-level extension workers of Ethiopia. The book is meant to be a resource book for trainers as well as an extension guide to weed management in Ethiopian crops.
Acknowledgments

The information in this book was based on the references sited in Annex 8. One of the most valuable texts was Weed Control in East African Crops by P. J. Terry. Special acknowledgements are extended to him particularly for the herbicide information on the various crops, Figure 7, and Figure 11. The International Plant Protection Center (IPPC) also provided much information from their past publications as well as ideas from a book to be published in the near future entitled Weed Control for Extension Workers.

The text was technically reviewed by selected researchers working on weed management or agronomy of the various crops from the Institute of Agricultural Research (IAR), Ethiopia. Technical reviews were also conducted by CIAT (haricot beans), CIP (potatoes), CIMMYT (wheat and barley), and ICARDA (faba beans, lentils, chickpeas, field peas) representatives working in Ethiopia. The Socio-economic Department of IAR reviewed the section on Problem Identification and Solutions. Mr Chris Parker, seconded to IAR by the World Bank, reviewed general weed control and control of specific problem weed sections. All comments were invaluable and much appreciated.

The artwork in the text was done by Ato Mandefro H/Giorgis, graphic designer of Addis Ababa.

The Crop Protection and Regulatory Department of Ministry of Agriculture provided invaluable assistance and support throughout the preparation of the manual.

I offer sincere thanks to all individuals who contributed support for this effort including the sponsors, FAO.
Chapter I

General Weed Control

Principles and Approaches
Weeds as Pests

DEFINITION OF A WEED

"A weed is a plant growing where it is not wanted by humans." It can be another crop plant or a wild species. Weeds are unwanted because they interfere with crop or animal production or are irritating to humans in other ways.

HOW WEEDS INTERFERE WITH PRODUCTION

Competition

Light, water, and nutrients are essential elements for plant growth. Any area can sustain only a given amount of plant biomass, whether crop or weeds. When any of these essential elements are limited and unable to supply the needs of both weeds and crops in an area, competition occurs, plant growth suffers, and crop yields are reduced.

The effect on the crop may be difficult to see. This is one reason why farmers, extensionists, and policy makers may not realize the damage weeds are doing to the crop. At other times, the crop will appear visibly stunted, perhaps yellow as a result of nutrient deficiency, or completely shaded under weed growth. In an average situation, where weeds are not removed from the crop, the farmer can expect a 30% yield reduction.

The following reductions due to delayed weeding have been reported in Institute of Agricultural Research experiments:

<table>
<thead>
<tr>
<th>Cereals</th>
<th>Pulses</th>
<th>Others</th>
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<tbody>
<tr>
<td>44% - maize</td>
<td>50% - lentil</td>
<td>62% - coffee</td>
</tr>
<tr>
<td>30% - sorghum</td>
<td>30% - chickpea</td>
<td>73% - cotton</td>
</tr>
<tr>
<td>35% - wheat</td>
<td>20% - faba bean</td>
<td>30% - peppers,</td>
</tr>
</tbody>
</table>
| 18% - barley | 36% - haricot bean | tomato (up to 100%)
| 30% - teff  | (up to 90%)    |              |
|             | 15% - field pea |              |
|             | (up to 67%)     |              |
|             | 50% - soybean   |              |
|             | (up to 75%)     |              |

1. Effects of Off-season Weed Growth

Where moisture is not a limiting factor in the system, weeds growing on fallow land can have a positive effect on nitrogen conservation. This is particularly important in systems where inorganic fertilizers are not used, as on many
small farms in Ethiopia, but where organic sources supply the nitrogen which is recycled in the system. In this instance, weeds should be controlled before crops are planted but their residues not removed from the system unless they are noxious like *Digitaria abyssinica*. In addition to adding nitrogen to the soil when weed residues are plowed under before seeding, weeds will also protect the soil by helping to prevent erosion. This strategy is useful to manage annual weeds which are normally not too aggressive, but perennial weeds are difficult to control and are often too competitive during the crop season.

If moisture is limited, as in semi-arid areas, it may be important to keep fallow areas weed-free in order to conserve the limited soil moisture. Weed cover increases water loss through both transpiration and evaporation because bare soil loses water only through evaporation. Plant cover can therefore decrease the 'pool' of available moisture during the crop season resulting in earlier competition either between crop plants and/or between the crop and weeds. The feasibility of this recommendation depends on:

- labor or machinery to clear the weeds;
- the possible necessity of using weeds for dry season animal feed; and
- elimination of weed cover may lead to erosion.

These three factors, and perhaps others, will determine the feasibility of weed removal during the dry season for any given situation.

2. Competition during Crop Growth

Crops are generally more sensitive to limitations of light, water, and nutrients at three growth stages: early growth, during fruiting and flowering, and during ripening. Of these three sensitive stages, damage done by weeds when both weeds and crops are small is most common and serious. This early stage is usually refered to as a 'critical period'. With experimentation we can show definite crop yield reductions if weeds are present during this period (See Figure 1). The actual number of weeks in the critical period depends on the crop, weeds present, and environmental factors.

3. Parasitic Weeds

Weeds such as *Striga* spp., *Orobanche* spp., and *Cuscuta* spp., live as obligate (total) or semi-parasites on specific crop plant hosts. They remove water and nutrients directly from the crop host, which weakens and stunts the crop and
produces a very low or no yield. These weeds are very difficult to control.

**Critical Period**

<table>
<thead>
<tr>
<th>Maximum in total absence of weeds</th>
<th>Kept weed-free for 'x' weeks, then allowed to become weedy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop yield</td>
<td>Weeds present for 'x' weeks then kept weed free until harvest</td>
</tr>
</tbody>
</table>

Number of weeks after crop emergence

Figure 1. The concept of critical period of weed competition (Adapted from Stephens, 1982)

4. **Factors Modifying Competition**

Factors related to the crop:

- **Species**—determines rate and extent of root and canopy development; therefore, spreading rate of ground cover.
- **Variety**—same as species.
- **Cropping system**—determines the mix of crop species as well as the timing of their growth in relation to each other.
- **Density and distribution**—the greater the density, the more competitive the crop. If the density exceeds a certain population, the crop will compete with itself and yield will be reduced. Generally, when the crop plants are planted equidistant from each other at an optimal
density, they are more competitive with weeds and less competitive with other crop plants.

- **Duration**—the amount of time the crop is present in relation to the weeds whether or not thinning takes place. The earlier the crop plant emerges compared to the weeds, the greater the advantage it has of using the limited resources.

Factors related to the weed:

- **Species**—determines rate of growth, and extent of root and canopy development.

- **Density and distribution**—the more dense the weeds, the greater the competitive effect on crops. The more even their distribution, then the greater will be the competition in any given area.

- **Duration**—the longer the weed is present, the greater its impact on the crop. If the weed emerges first, the competitive advantage will be for the weed.

These factors interact. They are affected by soil, climatic (rainfall, temperature) conditions, and altitude. This ultimately means that the competition encountered by a crop will change from one place to another depending on all the factors present in any given location (Figure 2).

![Diagram]

Figure 2. Summary of factors affecting the amount of competition present in any given situation.

5. Questions Pertinent to Agricultural Systems

Questions pertinent to agricultural systems can be raised considering Figure 2. Once these relationships are
understood for a given farm or field, recommendations for variety choice, spacing, population, intercropping combinations, etc., can be made with weed control and other production needs in mind.

Duration:

- At what stages of growth (critical period) does competition occur which will affect crop yield?
- Is relative time of emergence of the crop and weeds critical in determining effects?

Density and distribution:

- What effect is there on competition between crop plants (intraspecific) and between the crop and weeds (interspecific) when choosing crop population densities and spacing?
- What weed densities of the various species or species combinations cause crop yield reduction?

Species or variety:

- How do crop species or varieties vary in their competitiveness with weeds? How is this modified when different crop populations and spacings are used?
- How do different weed species compare in competitiveness?

Cropping systems:

- What combination of crops and timing of establishment of the crops offer a competitive situation to weeds?
- What cultural practices related to the various crops, when combined in a cropping system, provide a disadvantageous situation for weed growth?
- If an agroforestry system is used, what species and spacing combinations offer a competitive advantage to the crops?

Environmental factors:

- How are fertilizer and irrigation water, two controllable inputs, managed to the competitive advantage to the crop?
- How do crop and weed species interact with the environment and determine competitiveness? For example,
how does a species grown in a wet, cool higher altitude climate compare with when it is grown in a warmer climate with less rainfall?

- How does the environment modify different crop or weed densities which determine interspecific and intraspecific competition?

Limiting Land Farmed

Clearing vegetation before planting crops can be time consuming hard work, particularly in humid, high rainfall areas. This may be a deterrent to the amount of land prepared and planted.

The availability of labor or capital for weeding, may be a problem and limit the area the farmer prepares and plants. This situation occurs in areas where rainfall is high and plants grow fast or in areas where rainfall is limited but growing conditions favor vigorous weed growth. When rainfall is low and variable, competition for water can be serious; therefore, early and complete weeding is necessary. If the farmer cannot accomplish this on an extended area, he may limit the cultivated area and concentrate his labor.

Harvest Problems

Weeds may interfere and/or contaminate the harvested crop.

Weeds as Pest Hosts

Weeds may provide a habitat or serve as an attractant, alternative host, or feed for insects, diseases, birds, rodents and others. Some of these organisms may be beneficial, others harmful to crops. This may occur not only on weeds in the crop field but on weeds surrounding the field. The extension agent and the farmer must know about the different organisms to determine whether or not the weeds, particularly those at the edge of the field, pose a hazard. The weeds in the field will usually be removed.

Allelopathy

Some weeds (and crop plants) secrete toxic chemicals which cause crops to grow poorly. In some cases, for example when the residues have not had enough time to decompose before seeding the crop, toxins from decomposing weed residues may inhibit crop germination or growth. Some crop residues can have a similar effect on other crop plants or weeds. Residue toxins are more of a problem in cooler climates. Allelopathy and competition are jointly termed 'interference'.

7
Interfering with Irrigation and Reservoirs

Weeds may reduce water flow and increase water consumption.

Harm Humans and Animals

Certain weeds can be poisonous if eaten by animals, or may interfere with their digestion. They can cause irritation, skin rashes, or punctures (by thorns) to humans.

Reduce Crop Quality and Contaminate Seed

The presence of weed seeds, in particular, can reduce the value of the crop. *Cuscuta* in noug seed can cause rejection of the crop for an overseas market. *Bidens* in cotton lint can decrease the quality and increase the removal cost.

Control and Input Costs Wasted

Obviously weeds directly or indirectly cost money, time, and labor to control. In addition, the yield increases when using inputs such as fertilizer, water from irrigation, improved seed, and others will not be realized if weeds are not adequately controlled. Therefore, an indirect cost of production is the cost of these inputs which may be potentially wasted if weeds are not controlled.

| Table 1. Benefits and costs of weeds and weed control. |
|---------------------------------|-----------------|
| Benefits                        | Weeds Not Controlled | Costs                               |
| Limit soil erosion              | Reduce crop yields, limiting income and food |
| Domestic animal feed            | Interfer with harvest |
| Protect the soil against excessive sunlight | Limit the amount of land farmed |
| Food for humans                 | Reduce land value   |
| Recycle soil nutrients          | Poison humans and animals |
| Food and habitat for beneficial animals or insects | Use water and hinder water flow |
| Medicinal uses                  | Host crop pests     |
| Fuel                            | Reduce crop quality |
|                                 | Cause land abandonment |
|                                 | Provide a source of infestation |
BENEFICIAL EFFECTS OF WEEDS

As previously mentioned, weeds can help to recycle nitrogen, protect the soil from erosion, be used as a feed source for animals, and many other uses summarized in Table 1. Usually, there are trade-offs when making decisions whether or not to control weeds when they have both good and bad effects. It is important to evaluate their uses when these situations occur.

WEED CHARACTERISTICS

Importance of Understanding Weed Biology

- Identification.
  To help choose the correct control measure, especially when herbicides are used.

- Germination time.
  To help in timing cultivations, fertilizer application, planting time, and herbicide application.

- Factors affecting survival.
  To help in choosing and timing cultivations for desiccation of seeds and perenniating organs (underground tubers, rhizomes, stolons, bulbs, etc.)

- Period of growth and food storage.
  To assist in the timing of herbicide application and cultivations.

- Nature and position of perenniating organs in the soil.
  To assist in choosing the depth of cultivation for desiccation or control.

- Competitiveness of the weed.
  This will help to indicate conditions which are more suitable for the crop.

- Seed dormancy.
  Understanding dormancy can indicate whether dormancy can be encouraged (no soil disturbance) or to break dormancy (increase soil disturbance).

Life Cycle

Annuals - complete their life cycle in one season.
Perennials - live for a number of years or seasons.
Biennials - complete their life cycle in two growing seasons.
Many weeds, whether annuals or perennials, have vigorous fast growth and can produce seeds or vegetative reproductive parts quickly. Some have a short reproductive cycle which is conducive to survival and being competitive. Many weeds also are able to produce seed or vegetative reproductive parts in hostile environments. This characteristic ensures survival.

Reproduction

Annuals - can have many small seeds and be self-fertile.

Perennials - can reproduce by vegetative means and by seed. Vegetative reproductive parts include: tubers, rhizomes (below-ground stems), stolons (above-ground stems), bulbs, storage roots, corms, spreading roots, and tufts.

By having many propagules or more than one reproductive strategy, weeds ensure their survival and spread.

Dormancy

Seeds and vegetative parts can survive for long periods and still germinate when growing conditions are favorable. Most weed seeds have a discontinuous germination pattern. This means that, unlike crops, they do not germinate all at once. Both dormancy and discontinuous germination help weeds survive over time.

Dissemination

Weed seeds or capsules:

- have burs, hairs, and other structures that help attach them to animals and humans;
- have winged or feathery parts and are lightweight to aid transport by wind;
- are lightweight and have bladders to float in water;
- can be transported in soil on equipment, tools, or with transplants, straw, hay, crop waste, crop seeds;
- can be a contaminant of compost and sewage; and
- can be eaten by animals, carried, and spread in manure.

Similarity to Crops

Weed seed size or weight may be similar to crop seed and make it difficult to separate.
The weed may be similar, look like the crop, and have a similar life cycle. This may make removal by handweeding, cultivation, or herbicide difficult.

**Not Easily Controlled**

Noxious weeds, those difficult to control, have one or more of the following characteristics: fast life cycle; produce a large amount of seed; perennial growth; parasitism; difficult to remove (irritating to touch, hard to pull or cultivate so they regrow, look like the crop).

**SHIFTING WEED POPULATIONS**

After a major disturbance in nature, a succession of species predominate. Agricultural systems are similar, but there are frequent changes in the wild or natural species that occupy a field due to continued disturbance. Nearly all management practices will affect weed flora, encouraging some species while destroying others. The following factors will have an effect on what species are encouraged or discouraged:

- **Crop choices** - life cycle of weeds and crops, competitive ability of the crop, cropping patterns, crop combinations, and rotations.

- **Agronomic practices** - land preparation timing and method, time of planting, crop population, fertilization practices, drainage, weeding practices, treatment of harvest and weed residues, and fallow or off-season treatment of land.

The repeated use of any one weed control method or series of agronomic practices will permit the build-up of species that are not controlled by that method. This does not involve any genetic change in the non-susceptible species.

**INTEGRATION OF PRODUCTION AND WEED CONTROL MEASURES**

Any single weed control method will encourage some species while destroying others. For example, slashing destroys tall growing annuals but does not kill low-growing annuals or creeping perennials. Herbicides selectively kill some species but not others. Handweeding cannot readily remove weeds which are difficult to pull out entirely; weeds which resemble the crop plant; and weeds which re-root easily if not removed from the field. To ensure adequate weed control by avoiding selectivity when using only one method, choose a weed management system which is integrated. Use the most appropriate control measures given the biological, economic, and environmental conditions.
Agronomic practices also exert a selective pressure which affects the weed species. Therefore, weed control and other production practices must be varied in order to have an integrated approach to weed management. These general integrated methods are suggested: rotate crops, rotate and integrate weed control methods, and rotate and/or use herbicide combinations (if used). Crop rotation assumes that crops have unique agronomic practices associated with them, so that by rotating the crop the farmer is also varying the environment and changing the selective pressures on weeds.
Weed Control Principles and Methods

PREVENTION

1. Plant clean seed (free of weed seeds) and use clean soil for transplants.
2. Use seed screens or traps in irrigation canals.
3. Prevent weeds from seeding or spreading in the field, along the field edges, and along irrigation ditches.
4. Clean tools and equipment before cultivating a new field.
5. Livestock will spread weed seed in manure. If the seed they are spreading is from a noxious weed, try to restrict the animals' movement.
6. Quarantine. An effective quarantine system should both prevent new weeds from entering the country and spreading. Seed or propague inspection can determine if there is contamination. Seeds should be cleaned before issuing.

Most of these suggestions require extra labor. The economics for any given situation should be determined in order to help decide whether or not prevention is productive. It should be remembered that with particularly noxious weeds, which may not presently occur in great numbers, it may be economic to prevent their spread or entry into a new area.

ERADICATION

Eradication is the elimination of all weeds and weed parts from an area (usually a single noxious species). In most cases, this is uneconomic and not practical. It is possible to attempt this method if the weed is noxious, newly introduced, and has a limited distribution.

BASIC APPROACHES TO WEED CONTROL

Physical

This method removes weeds using physical or mechanical means: machine tillage with tractors or animals, mowing, hand pulling, hoeing, flooding, mulching, and burning.

Cultural

These methods involve any agronomic or management practice which enhances the crop's ability to compete with weeds:
selection of a competitive crop or variety, manipulation of
crop population and distribution, intercropping, fertilizer
placement method, planting time, and crop rotation.
Designing a successful cultural control program is the 'art
of vegetation management'.

Biological

This method uses a biological agent other than man to
control weeds. Multiple host agents are those that can
control a variety of weed species and are largely non­
specific. Examples are goats, sheep, geese, and fish. These
agents can be manipulated directly by man, are best used in
non-crop situations, and will show selectivity by preferring
certain species.

Specific host agents are insect or disease organisms that
affect a single host species.

Chemical

Herbicides will selectively control weeds; however, to use
them effectively requires specific conditions which may be
more limiting than for other control methods. The correct
herbicide must be selected for the particular crop and weed
spectrum present and it must be applied using a uniform
application at the correct rate at the correct time under
specific environmental conditions. Environmental conditions
affecting herbicide performance include: soil type, soil
organic matter content, soil moisture, rainfall,
temperature, humidity, and air movement.

POSITIVE AND NEGATIVE ASPECTS ABOUT WEED CONTROL MEASURES

Physical Methods

1. Handweeding

This may be the only practical method available to small
farmers. Other than requiring labor, it usually requires no
further cash outlay. This is an advantage in situations
where cash is not readily available but where labor is from
the farmer's immediate family or through non-cash exchange.
It may be the only method that can be used to weed
broadcast-seeded crops where herbicides are not available.

Handweeding is intensive and slow compared to other methods.
It may damage crop roots. Handweeding is usually delayed
until the weeds are easily seen and can be grasped. Yield
losses can occur before weeds are removed. Because
handweeding is intensive, farmers may wait until the weeds
are quite large so as to do only one weeding; whereas two weedings when the weeds are small is better in terms of reducing yield losses. In rainy weather, handweeding may be difficult and possibly damage the crop. If weeds are simply piled up after pulling, some species may re-root and grow again. Some weeds are not easily removed by handweeding: perennials, parasitic weeds when they are young, and others.

Handheld tools will make weeding faster and easier compared to handpulling, but have the same general advantages and disadvantages.

2. Mechanical weeding with animals or tractors

In order to use most methods of mechanical cultivation, the crops must be planted in rows that are spaced wide enough for the animal, tool, and farmer to pass without damaging the crop. The use of animal-drawn cultivators can make weeding faster and easier. It may not control the weeds in the crop row, but it can greatly reduce the time required for handweeding. If the correct implement is used at the correct speed when the weeds are small, it can throw enough soil into the crop row to bury and control small weeds without harming the crop. It is best done several times when the weeds are small, rather than when the weeds are bigger.

Crop injury may occur if roots are cut by the implement or by damaging edible tubers or rhizomes. Well-trained animals are necessary to avoid crop damage. Mechanical cultivation may be difficult to perform effectively in bad weather. It cannot be used on steep land. Sometimes the farmer must wait until the crop is large enough to see before cultivating, which may cause some yield reduction.

In the dry season, tillage can be used to bring perennial weed rhizomes or tubers to the surface so that they are killed by drying. Tillage can also sever roots. This may only be practical with tractor cultivation which can go deep enough. Tractors are expensive, require petrol and maintenance, need trained operators, and can compact soils.

3. Delayed tillage or stale seedbed

The seedbed is prepared well in advance of sowing. Weeds are allowed to germinate. A second shallow tillage kills small emerged and germinating weeds. This can be repeated if there is sufficient time. The crop is seeded directly after the last tillage. This method only works if there is sufficient moisture to encourage weed germination. This method kills many of the viable weeds before the crop becomes established.
4. **Blind tillage**

The field receives a shallow tillage after the crop is planted but before it emerges. Success depends on weeds germinating before or with the crop and on the crop tolerating the physical disturbance. Large-seeded crops such as maize and beans can tolerate this treatment without damage. Early weed competition is in part avoided with this method and the first weeding after crop emergence can be somewhat delayed, helping when there are labor shortages.

5. **Minimum or zero tillage**

Many problem weeds, usually associated with annual crops, only survive in disturbed or tilled soil. Therefore, there may be some advantage to reducing the amount of tillage in order to control some weed species. Experiments have shown variable responses to minimum tillage on different soil types and under different rainfall regimes. This method should be used with caution, particularly in higher rainfall areas where there is extensive weed growth. It is important to fully understand the impact on production that this method may have.

The loss of tillage for weed control means that another method must be used. This is usually a herbicide. Perennial weeds may become more of a problem in the absence of soil disturbance. Placement of weed, fertilizer, and pesticides may be difficult without different equipment. Crop residues may pose problems in getting good seed-to-soil contact.

Minimum tillage can be advantageous in semi-arid conditions where there are few weeds at the beginning of the season. Strip tillage can speed planting in situations where rain is variable and unreliable. Because this takes less labor and is faster, labor and animals will be available to start timely weeding. If weeds have germinated before planting and if there is no herbicide available to control weeds, this method will make weed competition problems.

6. **Mowing, slashing, or cutting**

Removing the majority of the above-ground portion of the weed will help to control many weed problems, such as competition for light or interference with harvest. The portion of the plant remaining can protect the soil from erosion. This method is suitable for controlling weeds in pastures, ditch banks, on field edges, and between the rows of some perennial crops.

Mowing is ineffective for controlling creeping or low
growing weeds. It does not completely eliminate competition from weeds in perennial crops.

7. **Flooding**

This is suitable for crops such as rice which can withstand flooding. It is only useful where the fields are relatively flat and on soils that will keep water from quickly moving into the ground. In some situations, flooding can be used during the fallow period to eliminate problematic perennial weeds. After drainage, upland crops can be planted. It is not a suitable method for most of Ethiopia.

8. **Mulching**

This weed control technique is most often used on high value crops on small areas. Besides weed control, other benefits include soil moisture conservation, reduced erosion, and reduced soil temperature. Plants may be moved and left where they fall, or gathered, stored, and used later as mulch. Care should be taken to make sure that mulch does not contain weed or crop seeds. Plastic sheets can also be used, but are expensive in addition to the labor for field placement.

Finding mulch in semi-arid areas is not often practical. Material useful for mulch may have a greater value as animal feed. Mulch made from plant material may attract termites. Growing mulch in situ is possible, such as leguminous agroforestry species which can be pruned and applied as mulch. Grasses such as napier grass can be cut and used as mulch. Both methods can be useful to minimize the labor associated with cutting, carrying, and applying mulch.

9. **Burning**

This method is used to get rid of undesirable crop residues which may harbor diseases as well as weed seeds. It is also used on pasture areas to encourage more palatable species. It is generally not useful in most Ethiopian conditions.

Burning, like all weed control measures, is selective. Many species will not be harmed by burning. Roots, seeds, and vegetative propagules beneath the soil surface will not be killed and are a source of reinfestation. Burning residues destroys much of the nitrogen contained in the residues, may result in soil erosion, destroys any soil conditioning effects of the residues, and may reduce water infiltration and water storage by causing the soil surface to repel water.
Cultural Methods

1. Crop competition

A farmer's selection of a crop is governed by many factors: economics, biological, preference of a variety, disease resistance or tolerance, as well as competitiveness with weeds. Therefore, unless there is a serious weed problem, other factors may determine crop choice.

A crop or crop variety which competes with weeds has the following characteristics: emerges and grows quickly, produces abundant leaves, and rapidly expands its canopy to meet adjacent plants shading the weeds.

Crop competition can be enhanced by choosing a density and arrangement for the crop or combination of crops (intercropping) so that the maximum space will be occupied in the shortest time by crops rather than weeds. Other factors which will determine density and spacing are available soil moisture, equipment or animals used in cultivation row planting, and plant diseases. These factors may be strong determinants in the choice, particularly in limited soil moisture conditions in semi-arid areas.

Relay cropping, where one crop is seeded after the establishment of another crop, can be very useful in creating a competitive situation with weeds. Many farmers will plant a second, minor crop into the major crop after or simultaneously with the first weeding.

Living mulch crops, those having a food or forage value, can be grown between crop rows, replacing weedy species. This can be a useful technique in perennial crops such as coffee when land is limited. There is an additional advantage if the species are nitrogen fixing and useful in controlling erosion.

2. Planting time

Generally, if a crop is planted at a time which favors rapid growth, it will be more competitive with weeds. In many cases however, planting time coincides with the rain, available labor or animals, or higher market prices. At any rate, planting as soon after land preparation as possible will help to eliminate the possibility of weeds germinating before the crop. In higher rainfall areas, the first planting may be delayed until the first flush of weeds has been destroyed.
3. Fertilizer placement and timing

Banding fertilizer, placing it near the crop plant so that it is available to the crop and not the weeds, is the method recommended when row planting. This may result in greater weed growth in the row near the crop plants but if the application of nitrogen can be delayed until top dressing, competition with weeds in the row may be reduced. Using a banded application technique may require special tools or more labor. Therefore, it may not be feasible in all situations.

Fertilizer should be applied when the plants can use it, not too early or too late. This is also true for manure. A split application is often useful. In semi-arid areas, it may be best to wait to apply the fertilizer until the amount of rainfall is over the critical level, and the farmer knows there is a good chance for crop growth.

4. Crop rotation

By changing from one crop to another, the different growth habits and associated agronomic practices will help to change the environmental and management conditions encountered by the weeds. This represents a change of strategy which will help to avoid selective pressures which may favor one species over another. Planting time, spacing, number of cultivations, time of harvest, method of land preparation, and seeding all may differ. For example, a high value crop receiving intensive weed control may be followed by a crop which is lower in value but sensitive to weed competition. Weed problems should be reduced.

5. Water management

In irrigated areas, water can be managed to encourage crop growth but not weed growth. Pre-irrigation can also be useful to encourage weeds to germinate before the crop is planted. The germinated weeds are then killed by cultivation. This is a successful control measure for perennial sedges.

Biological Control Methods

This method can be advantageous:

- useful in inaccessible areas;
- useful on lower value, extensive areas such as grazing land;
- can be self-perpetuating;
- relatively inexpensive after establishment; and
Chemical Methods

Advantages to herbicides are:
- possibly the only solution to a serious weed problem;
- potentially less expensive than other weed control methods;
- may be faster than other methods;
- weeds are controlled early during the critical period, when other methods may not be effective;
- maximum cropping of land may be encouraged because of a lower labor requirement;
- less labor is required compared to other methods; and
- can be combined with other weed control techniques to make an integrated program.

Disadvantages include:
- risk of ineffective weed control and injury to crops;
- spray drift may injure non-target organisms;
- possible herbicide residues may be left which would injure the subsequent crop;
- expensive and uses limited foreign exchange;
- lack of trained farmers and extension personnel leading to misapplication problems;
- lack of protective clothing, proper storage and mixing facilities which may increase the chances of accidents and harm to humans and animals; and
- requirement of purchase, operation and maintenance of spray equipment may not be met and lead to faulty application.

VEGETATION MANAGEMENT

The goal of weed control is to limit their negative effects to the point of acceptability. The strategy is to create
conditions favoring desired plants (crops) while suppressing unwanted plants (weeds). Vegetation management leaves as few niches as possible for weeds (for example, by using a competitive crop variety which is closely spaced), and disrupts available niches so weeds cannot invade, (for example, using cultivation, herbicides, etc.).

Weeds have both beneficial and negative characteristics. The presence of weeds in the crop field does not necessarily mean that they are having a negative, competitive effect on the crop. For example, if the weed is useful as human food and is not having any negative effect on the primary crop, it would not be economical to remove them in order to have a clean crop. Therefore, before making a judgement whether weeds pose a problem, it is necessary to determine the beneficial attributes of the weed and whether its presence is actually detrimental.

A weed may be useful but at the same time decrease the primary crop yield. In this case, the trade-offs need to be considered and a decision made about weed control which is acceptable to the farmer.

The extent of vegetation management in each situation will vary depending on many factors such as crop and weed species, but also on economic factors such as labor availability, market price, cost of control measures, etc.

For example:

- An expensive, intensive weed control program would not be warranted in a low value crop.

- If a high value crop is following a low value crop, then better weed control in the current low value crop would be an investment in the future.

- A one time, expensive weed control treatment to eliminate a noxious weed may be worthwhile when costing the control over the next several years when the beneficial effect is still being realized.
General Information About Chemical Weed Control

TYPES OF HERBICIDES

Herbicides can be classified using several systems. They can be classified as selective or non-selective; foliage applied or soil applied; contact or translocated; plant type controlled; by time of application; or by family. The most common classification system is by family. Each family has distinctive characteristics, but within a family their use and plants which they kill varies. The most commonly used families are listed below with their major characteristics.

Hormonal herbicides

- Act similarly to natural growth regulators but because they are applied in a much higher concentration, are not broken down by the plant's enzymes. They disrupt growth processes such as cell division, cell differentiation, cell elongation, etc.
- More toxic to broadleaf plants than to grasses.
- Usually applied to the foliage.
- Relatively short lived in the soil.
- Broken down in the soil by microorganisms.
- Used selectively in small grain crops, pastures, and non-crop areas.

There are three chemical groups in this family based on their chemical structure:

<table>
<thead>
<tr>
<th>Phenoxo</th>
<th>Benzoic acid</th>
<th>Picolinic acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,4-D</td>
<td>dicamba</td>
<td>picloram</td>
</tr>
<tr>
<td>2,4-DB</td>
<td>chloramben</td>
<td>triclopyr</td>
</tr>
<tr>
<td>2,4-DP (diclorprop)</td>
<td></td>
<td>2,3,6-TBA</td>
</tr>
<tr>
<td>2,4,5-TP (silvex)</td>
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<tr>
<td>MCPA</td>
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<tr>
<td>MCPB</td>
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<tr>
<td>mecoprop</td>
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</tbody>
</table>

Triazines, ureas and uracils

- All are soil applied but some have foliar activity as well.
- All are effective against selected germinating broadleaf and grass weeds.
- Are taken up by the roots and move in the xylem.
- Most do not move into the soil easily and have to be activated by rain or overhead irrigation to move them into the soil.
- Physiological tolerance is the main reason for selectivity. However, another way of being selective is through differences in plant rooting depth. The herbicides stay in the top layers of the soil. Weeds germinating in this layer are killed and crops or weeds having their roots below this layer are not affected.
- The amount of movement of the herbicide depends upon the solubility of the herbicide, the type and quality of the clay in the soil, the organic matter content of the soil, and the moisture content of the soil at the time of application, as well as how soon rain or supplementary irrigation follows after herbicide application.
- Photosynthesis is inhibited by these herbicides.
- Volatility and photodecomposition is low; therefore, the herbicide can stay on the soil surface for a long time.
- Some of them are persistent and can cause problems to subsequent crops.
- They have low mammalian toxicity.
- They are slow to act on susceptible weeds.

The three chemical groups are:

<table>
<thead>
<tr>
<th>Triazines</th>
<th>Substituted ureas</th>
<th>Uracils</th>
</tr>
</thead>
<tbody>
<tr>
<td>atrazine</td>
<td>diuron</td>
<td>bromacil</td>
</tr>
<tr>
<td>simazine</td>
<td>chlortoluron</td>
<td>terbacil</td>
</tr>
<tr>
<td>cyanazine</td>
<td>linuron</td>
<td></td>
</tr>
<tr>
<td>metribuzin</td>
<td>monuron</td>
<td></td>
</tr>
<tr>
<td>propazine</td>
<td>fluometuron</td>
<td></td>
</tr>
<tr>
<td>ametryn</td>
<td>chlorbromuron</td>
<td></td>
</tr>
<tr>
<td>prometryn</td>
<td>chloroxuron</td>
<td></td>
</tr>
<tr>
<td>terbutryn</td>
<td>isoproturon</td>
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<tr>
<td></td>
<td>thiazuron</td>
<td></td>
</tr>
</tbody>
</table>

Acid amides

This family is sometimes also called acetanilide.

- Most effective against seedling grasses, but also control some annual broadleaved weeds.
They have low mammalian toxicity.

Usually applied to the soil pre-emergence. Incorporation following rain, sprinkler irrigation or tillage improves performance.

Propanil is an exception in this group because it is applied to foliage.

Soil-applied chemicals in this group inhibit germination and cell elongation of emerging roots and shoots.

Primarily absorbed by roots and shoots, depending on the particular herbicide and weed.

Selectivity is primarily due to differences in biochemical processes in the plants.

Have relatively short persistence in soil with considerable microbial degradation.

Examples include: alachlor, metolachlor, bensulide, propachlor, butachlor, napropamide, diphenamid, metazachlor, and propyzamide.

**Carbamates**

- Fairly volatile.

- Microbial degradation is fast under warm, moist conditions.

- Rain, overhead irrigation or mechanical incorporation is needed.

- Many germinating and seedling grasses and some broadleafed weeds are controlled.

- Absorbed throughout the growing points of emerging grasses and to a lesser degree through the roots.

- Inhibit cell division.

Examples are: propham, chlorpropham, barban, and asulam.

**Thiocarbamates**

- Require mechanical incorporation into the soil because of their extreme volatility.

- Most effective against annual grasses, but also can
control some perennial grasses and some broadleafed weeds.

- Absorbed mostly through the shoot of the plant.
- Inhibit cell division.
- Biologically active in the soil for only a few weeks.

Examples include: EPTC, vernolate, triallate, butylate, cycloate, pebulate, CDEC, and diallate.

**Dinitroanilines**

- Soil applied and most require mechanical cultivation for incorporation because they are not very soluble in water, can be easily decomposed by sun (photodecomposition), and are somewhat volatile.
- Most effective against germinating seedling grasses, but also control some broadleafed weeds.
- Absorbed by roots and shoots but do not move in the plant very readily.
- Inhibit cell division in the germinating seedlings.
- Selectivity is often governed by placement of the herbicide in the soil.
- May be some problems under certain conditions from residues, which may effect subsequent crops.

Examples include: trifluralin, pendimethalin, benefin, oryzalin, fluchloralin, and ethalfluralin.

**Bipyridyliums**

- Foliar applied.
- Contact herbicides which have very little movement in the plant.
- Give good control of most annual weeds but poor control of perennials because the chemicals do not move into the underground portion of the plant to kill tubers, rhizomes, etc.
- Highly soluble in water.
- No soil activity.
• Symptoms appear quickly on affected plants.
• Work faster under sunny conditions.
• Non-selective; selectivity is achieved by directing the spray away from crop plants or by making the application when the crop is dormant or not yet planted.
• They are very toxic if swallowed and very irritating to the skin. USE WITH EXTREME CAUTION.

Examples include: diquat and paraquat

Substituted glycine
• Applied to actively growing foliage.
• Moves throughout the plant with the plant sugars (phloem).
• Almost no soil activity.
• Not volatile.
• Slower acting than the bipyridyliums.
• Non-selective and kills most annuals and perennial grasses and broadleafed weeds.
• Can be used in both non-cropland and cropped land.
• Selectivity is achieved by differential timing of application or placement.
• Most often applied before planting (pre-plant).

An example is glyphosate.

Double ring grass killers ("graminicides")
• Effective against most grasses but have no effect on broadleafed species.
• Foliage applied.
• Little or no soil activity.
• Most are slow to act.
• All are very toxic to maize and sorghum.
Sensitive weed species have slowed growth soon after treatment, then turn yellow perhaps with some reddened color, and then die.

Examples are fluazifop-butyl and diclofop-methyl.

Other families

- benzonitrile - bromoxynil, ioxynil
- halogenated aliphatic acids - dalapon
- phthalic acids - DCPA
- sethoxydim

SELECTIVITY

Selectivity is the result of a herbicide reaching and disrupting the growth functions of one plant (weed) but not other plants (crops). For a herbicide to be toxic to a plant it must do four things: contact the target (foliage or roots); penetrate the plant; move within the plant to the site of disruption; and lastly, disrupt the growth process (photosynthesis, cell division, protein synthesis, or others).

These are four major types of selectivity. In any given situation, one or more of these types may be working.

Selectivity is relative. It can be affected by environmental conditions as well as by different application rates of the herbicide.

Contacting the Plant

1. Herbicide placement

Herbicides can be physically kept from contacting plants that would normally be susceptible but which you do not want to kill. This can be done by using spray shields, or intentionally directing sprays away from the crop. Paraquat is often used in this way.

The rooting depth of a plant may be the basis for selectivity. The herbicide, such as in the triazine family, may stay in the upper layers of the soil where it will only affect plants with roots in the same zone of the soil. Plants with roots below this layer will not be affected. This technique can be used with deep-rooted perennial crops to control shallow-rooted annual weeds.
2. Time of application

Herbicides which have no soil activity or are quickly deactivated in the soil can be applied just prior to planting or emergence of the crop to kill any emerged weeds. This would be pre-emergence to the crop but post emergence to the weeds. This is how the non-selective herbicides paraquat and glyphosate are often used.

Herbicides may also be sprayed during a 'tolerant' phase of a crop to avoid injury. This is dependent upon a particular physiological stage of the crop. For example, wheat is tolerant to 2,4-D when it is in the late tillering stage, but sensitive to injury from germination to the four leaf stage. Some herbicides may also be applied when the crop is dormant.

Penetration into the Plant

Physical characteristics such as morphology or anatomy, the nature of the leaf surface, or the location of the growing points of a plant can affect selectivity.

1. Plant morphology

The shape, size, and position of the leaves can affect the amount of herbicide that contacts and therefore penetrates the leaf. Broad, flat leaves will retain more herbicide than narrow, thin leaves.

2. Nature of the leaf surface

The thickness of the wax, the roughness, amount of corregation, and the hairiness on the leaf surface will influence how much herbicide will penetrate the leaf. A waxy or highly corrugated surface or one that has a lot of hairs will reduce the amount of herbicide able to contact the leaf surface and hence penetrate.

3. Location of the growing point

Growing points which are above ground or at the soil surface, as in most broadleaf weeds and annual grasses, will be more easily contacted by herbicides. Many perennial grasses, however, can have growing points underground and can be less easily contacted by some herbicides.

Movement in the Plant

Movement of a herbicide inside a plant may be different in tolerant and susceptible species. In a sensitive plant,
enough herbicide moves to the site of action quickly to kill the plant. Movement may be slower or blocked in a tolerant plant.

Metabolism

Some tolerant plants have the ability to metabolize or break down the herbicide once it is inside. The break down products are no longer harmful. There are cases where cultivars or varieties of crops differ in their sensitivity to herbicides. This is usually due to physiological differences. The same species of weeds growing in different places can also differ in their sensitivity to herbicides because of slight differences in morphology or physiology. Weeds of the same species but with slight differences are called ecotypes or biotypes.

These last two characteristics are inherent in some plants and are not under direct control of the applicator, whereas timing and placement are types of selectivity in control of the applicator.

FACTORS AFFECTING FOLIAR APPLIED HERBICIDES

In order for a foliar-applied herbicide (one that is applied post emergence) to be effective, it must reach the plant, be retained on the leaf, penetrate, move to the site of destruction, and be toxic to kill the plant.

Barriers to the Herbicide Reaching the Plant

1. Spray drift

Small droplets (nozzles too small or pressure too high) are more subject to drift. Wind or a nozzle too far off the ground will also cause drift.

2. Volatilization

This is when the liquid herbicide changes into a gas, which depends on the nature of the chemical and how susceptible it is to this sort of change. Temperature, relative humidity, and wind also may affect whether or not a herbicide is volatile. If this happens, there is loss of herbicide activity because less chemical remains on the plant.

3. Canopy effect

Target plants may be protected by taller, leafy plants so that the herbicide does not reach them in a large enough quantity. If this is a problem, use a larger volume of water
in the spray solution and/or increase the pressure of the sprayer.

Retention on the Leaf

1. **Plant morphology**

See discussion under selectivity. A plant with upright, narrow leaves or with a corrugated surface will be more likely to have the herbicide retained on the leaf. The herbicide may be modified by the addition of adjuvants such as spreaders (which will help the herbicide spread out on the leaf rather than stay in one droplet); stickers (which will help the herbicide stick to the leaf); and wetting agents and oils (to help it stay on the leaf and to penetrate).

2. **Washoff problems**

This is due to rain, irrigation, heavy dew, or a spray volume that is too high.

3. **Volatility**

See discussion above.

Once the herbicide is retained on the leaf it can: remain there as a crystal; enter the cuticle and become dissolved in the wax and become unavailable; or it may enter the vascular system and move into the plant.

**Movement into the Leaf and Throughout the Plant**

The lower leaf surface is usually more permeable to herbicides. The herbicide can enter through stomates (the tiny holes in the leaf where there is gas exchange) or through the cuticle. This stage is affected by humidity. If the humidity is high, then the spray solution will evaporate more slowly, and there will be more time for the droplet to penetrate the leaf. High humidity also makes it easier for water-soluble chemicals to penetrate the cuticle.

The herbicide can move inside the plant in the symplast, the apoplast, or both. The symplast is the interconnected, living cells, including the phloem, which actively transports sugars produced in photosynthesis. The apoplast or xylem is an interconnected network of non-living cells and cell walls which transports water and other nutrients. The symplast is usually the most important system for foliage-applied materials and the apoplast the dominant system for transporting soil-applied herbicides, taken up by the roots.
Figure 3. Fate of post-emergence applied herbicides
'Source to sink' - 'Sink' is the site in the plant where sugars are used for growth processes or where they are stored. The source is where the sugars are produced, e.g., the leaves. Sugars tend to move from the leaves (source) toward the sink and carry along some of the post-emergence herbicides such as 2,4-D or glyphosate, which cannot move by themselves.

For perennial weed control, timing of the application is important to transport the herbicide to kill the underground parts. If the plant is newly emerged, then the sugars being produced will be translocated to areas of new growth. When the plant is older, the sugars will be moved into storage tissues. It is at this time when herbicide application will be most effective.

FACTORS AFFECTING SOIL APPLIED HERBICIDES

A soil-applied herbicide is taken up by roots or emerging shoots of weeds and is usually applied before the crop is planted or emerged. The major factor determining the effectiveness of a soil-applied herbicide is its availability to weeds: the herbicide must be in the right place, at a high enough concentration, and for sufficient time, to achieve weed kill.

Processes in the Soil Affecting Herbicide Availability

1. Adsorption

This is the chemical and physical attraction of a substance to a surface. In this case, the herbicide is attracted to a soil particle. When this occurs, the herbicide is not available for uptake by plants as only herbicide molecules in the soil solution are available.

The extent of adsorption is affected by soil texture, clay type, organic matter content, and soil moisture. The smaller the soil particles, the greater the surface area and therefore, potentially more adsorption occurs. Clay will adsorb more herbicide than sand. Organic matter also adsorbs herbicides; therefore, the higher the organic content, the greater the adsorption and less herbicide will be available for plant uptake. The drier the soil, the greater will be the adsorption. If the soil is moist, some of the sites for adsorption will be occupied by water molecules, fewer sites will be available for the herbicide molecules.

2. Photodecomposition

Light breaks down the herbicide and deactivates it.
Trifluralin is an example of a herbicide that is affected. This can be overcome by incorporating the herbicide into the soil.

3. Leaching

The amount of herbicide that leaches through the soil depends on the solubility of the herbicide, the amount of water, the soil texture, and the adsorptive capacity of the soil. It is a process that can make herbicides either available or unavailable to plants depending on how much leaching or movement has taken place.

4. Chemical decomposition

This chemical process occurs when reactions in the soil cause the herbicide to change or breakdown.

5. Microbial breakdown

This is one of the major methods of decomposition of herbicides in the soil. The rate at which the breakdown occurs depends on environmental conditions, as well as the inherent nature of the herbicide. Generally, warm, moist conditions favor microbial activity and hence the breakdown of the herbicide. Some herbicides will last only a short time (glyphosate), while others can persist for more than one year.

6. Soil moisture

Of all the environmental factors, soil moisture is one of the most important. Poor moisture conditions, either too much or too little, cause more failures with soil-applied herbicides. Moisture is needed to help incorporate many of the herbicides with low solubility. Sufficient moisture is also needed to make a herbicide available for uptake because it is taken up with the soil solution.

REVIEW OF THE FATE OF HERBICIDES

After the herbicide leaves the sprayer, many things can happen to it:

Before reaching the plant, it can drift away, be volatilized (changed to a gas); or be decomposed by sunlight (photodecomposition).

A soil-applied herbicide can be leached (moved with water down deeply into the soil where it is unavailable); deactivated by microorganisms which break it down; adsorbed
Figure 4. Fate of herbicides applied to the soil
(strongly attached) to soil particles, particularly clay and organic matter; or washed away with eroded soil.

Foliar-applied materials can be washed from the plant by rain or can run off the leaf because of the leaf angle or waxy surface.

Once the herbicide is inside the plant it can move directly to the site of action, be metabolized (broken down), or be stored in a vacuole (within the plant cell where it is unavailable to the plant's metabolic processes).

FORMULATIONS

No herbicide is sold containing 100% active ingredient. Instead the manufacturer 'formulates' the herbicide which is called the 'technical material', with inert or inactive components such as solvents, stickers, surfactants, wetting agents, and carriers. Concerns in formulating a herbicide include: solubility or miscibility (mixability) in water, volatility, retention and penetration on the target plant, shelf life, inflammability, toxicity to the user, and cost of materials, containers, and transport.

Types of Formulations

1. Water soluble concentrates

The active ingredient can be dissolved in water. It may be sold as a dry powder or already dissolved in a concentrate for further dilution by the user.

2. Emulsifiable concentrates

The active ingredient is soluble in an organic solvent such as an oil. An emulsifying agent is added so that it will mix with water. When diluted with water for spraying, the solution appears milky.

3. Wettable powders

If the active ingredient is not soluble in water or an organic solvent, it can be ground into fine particles and formulated as a wettable powder. Wetting and dispersing agents are added to keep the particles in suspension. These formulations must be agitated constantly to keep the material from settling to the bottom of the sprayer.

4. Flowable

This is a finely ground powder suspended in water. This
slurry mixes readily with water and is easier to handle than a wettable powder.

5. **Dispersible granules**

These are small beads that are added to water to form a suspension. They are also easier to handle than wettable powders and are dust-free when pouring.

6. **Granular compounds**

These are applied dry rather than being mixed with water. Most granular herbicides are also marketed as wettable powders or liquids. They are spread over the soil with special applicators. They are particularly useful where there is inconsistent weather or limited rainfall. They tend to be more expensive than more concentrated formulations. They usually contain less than 10% active ingredient.

**ADJUVANTS FOR HERBICIDES**

An adjuvant is a substance that is added to the pesticide in the spray mixture. It can: improve wetting, reduce drift, reduce evaporation, increase penetration, slow release, improve translocation, extend persistence, etc. Surfactants, wetting agents, and oils are three important adjuvants.

**Types of Adjuvants**

1. **Surfactant**

   This is a surface active chemical that facilitates wetting, dispersing, emulsifying, spreading, sticking, or other surface-modifying characteristics.

2. **Wetting agents**

   These substances create a better contact between the treated surface and the spray by reducing the surface tension of the droplets, which increases the spread of spray droplets.

3. **Oils**

   Oils are adjuvants but not surfactants. They are added to increase the activity of the herbicide and in some cases can act as herbicides themselves.

4. **Emulsifier**

   This substance promotes the suspension of one liquid in another.
5. Sticker

This increases herbicide adhesion to the plant surface.
Application of Herbicides

PESTICIDE SAFETY

Pesticides are poisons. Their use or abuse determines the end results of whether they are useful or harmful.

Toxicity versus Hazard

- Toxicity is how poisonous the compound is.
- Hazard or danger is the chance of harm.
- Toxic compounds are hazardous but careful handling reduces the hazard.
- Likewise, low toxicity compounds can become hazardous if handled unwise.

Types of Toxicity to People

- Acute toxicity results from a single dose.
- Chronic toxicity results from small doses repeated over time.
- LD50 is a guide to toxicity. The dose required to kill 50% of the test animals (usually rats, not humans) when taken orally or when put on the skin (dermal). The number expressed as: mg pesticide/kg body weight. A LOW LD50 means HIGH TOXICITY.

*Example: Pesticide A: LD50 = 6 mg/kg

and

Pesticide B: LD50 = 800 mg/kg

Person weighs 70 kg.

If LD50 = 6, then 6 mg/kg x 70 kg = 420 mg = 0.42 g of pesticide A are needed to kill 50%.

If LD50 = 800, then 800 mg/kg x 70 kg = 56,000 kg = 56.00 g of pesticide B are needed to kill 50%.

0.42 g and 56.00 g are the amounts of material that have to be ingested to achieve the same effect. Therefore, the LD50 of 800 indicates a less toxic chemical because a person would have to ingest much more to achieve the same effect.

LD50 IS A RELATIVE GUIDE OF TOXICITY; IT IS NOT A SAFE DOSE!
Factors Affecting Hazard

1. Route of exposure
   - Oral exposure occurs when food products are contaminated with pesticides, when pesticides are mistakenly eaten as food or drink, or when pesticides are swallowed by accident. Oral exposure is probably the least common form of accidental contamination.
   - Dermal exposure occurs through spills on the skin, or failure to protect the body when mixing or applying pesticides. This is the most common form of exposure.
   - Inhalation or breathing in of dusts, vapors, and spray mists is the most dangerous form of exposure. After entering the lungs, the pesticide can quickly enter the bloodstream. Awareness of this form of exposure is usually low, thus people do not take the necessary precautions such as wearing respirators and masks.

2. Application methods
   - A fine mist or dust will increase the hazard.
   - Spraying during the hottest time of the day increases volatilization and therefore chance of inhalation.
   - Spraying under windy conditions increases chance of drift, and dermal and inhalation exposure.
   - Spraying directly in front of yourself increases bodily and dermal exposure. Therefore, have the nozzle and boom to the side whenever possible.

3. Frequency of Use
   - The more frequently pesticides are used, the greater the chance of contamination.

4. Type of Formulation
   - Liquid formulations are usually more hazardous than solid formulations because they are already in solution and can penetrate the skin more easily.
   - However, liquid formulations are easier to pour and measure than powders or dusts.
   - The solvents used in liquid formulations can be toxic, whereas the carriers for solids are usually not harmful.
Figure 5. Routes of exposure to pesticides and prevention methods.
5. Persistence

The greater the persistence of a material, the greater the period and possibility of contamination.

Safety Precautions

1. Use the proper pesticide and amount needed for the job. Check for alternative control measures which may be as effective but less hazardous than pesticides. Do not choose a very toxic pesticide even if it is the most effective one, unless you can guarantee safe and correct application by skilled operators using a tractor sprayer and wearing protective clothing at all times.

2. Read the label. Follow the instructions carefully.

3. Transport pesticides safely. Avoid contact with rain and hot sun. Avoid carrying with foodstuffs. Keep pesticides away from passengers and livestock.

4. Use protective clothing. Use gloves, overalls, boots, goggles, masks. Bring extra clothing in case what you are wearing becomes contaminated.

5. Avoid eating, smoking, and drinking when using pesticides.

6. Clean up after use. Wash body, clothes, equipment after applying pesticides. Dispose of equipment wash water in a waste area.

7. Check and maintain equipment to avoid accidents.

8. Educate and train pesticide applicators.

9. Mixing:
   - Never stir or dip with hands.
   - Never suck through a tube.
   - Always clean measuring equipment immediately after use.
   - Always close containers immediately after use.
   - Read the label or use instructions to check.
   - Mix only the amount that you will use that day.
   - Do not mix near children or livestock.
10. Use in the field:

- Keep people out, especially children.
- Re-read the label
- Avoid spraying into the wind or when it is likely to rain.
- Do not clean plugged nozzles with your mouth or sharp objects.
- Never leave equipment or materials unattended.
- Collect all waste and dispose of it as described below.
- Do not walk through the treated crop. Only re-enter the field after it is safe. Read the label for information on re-entry time. This applies mainly for insecticides and some fungicides.

Pesticide Disposal

1. Avoid surplus

Calculate and buy only what you need.

2. Spray out excess on a waste area

Spread the pesticide rather than concentrate it. Avoid contaminating ponds or irrigation ditches that may be used as sources of drinking water.

3. Container disposal

Metal cans and drums should be punctured and buried; cardboard boxes burned; plastic bags punctured and either buried or burned. When burning materials, keep people and animals away from the fumes and flame to avoid breathing toxic fumes.

4. Clean the sprayer

Partially fill with some clean water, mix and spray over a waste area. Repeat several times so there is no residue left.

5. Spills

In case of a spill, cover with an absorbent material such as ash, sawdust, or soil. Clear away this material and bury it.
Avoid contaminating yourself with it. Wash the exposed area with water to dilute any further residue.

Storage

1. Keep pesticides away from living areas, animals, children, food, and water.

2. Lock the pesticide storage area and place a warning sign.

3. Environment should be dry, dark conditions to give longer, safer storage.

4. Check periodically for leaks in containers. If you find a leak you must either decant the pesticide into a new container or dispose of it. Contact the Crop Protection and Regulatory Department, Pesticide Section for disposal advice.

5. Age of the pesticide. As a general rule of thumb, a pesticide should only be stored for a two-year period in the tropics.

6. Avoid storing pesticides if at all possible. Calculate the amount you need and use it up.

First Aid

1. Symptoms of poisoning
   - Mild - headache, nausea, dizziness, and irritation
   - Moderate - vomiting, blurred vision, stomach cramps, rapid pulse, excessive perspiration, constricted eye pupils, trembling, and nervous distress.
   - Severe - convulsions, respiratory failure, loss of consciousness, loss of pulse, and DEATH.

2. Treatment of the victim

   IDENTIFY THE MATERIAL AND ROUTE OF EXPOSURE.
   - Unconscious - clear air passage, put patient on his side with head extended and lower than the stomach.
   - Convulsion - prevent patient from hurting himself; place twisted handkerchief in the mouth to prevent him from biting his tongue.

GET DOCTOR’S HELP IMMEDIATELY!!
■ Oral exposure - TAKE VICTIM TO THE DOCTOR. Provide label or container with contents. Keep patient calm, warm, comfortable. Do not induce vomiting unless recommended on the label.

■ Inhaled exposure - remove from contaminated area; loosen clothing; SEEK MEDICAL HELP.

■ Exposure to eyes - wash eyes with clean water for 15 minutes; cover the eyes; SEE A DOCTOR.

■ Dermal exposure - remove contaminated clothing; wash immediately with soap and water; wipe off as much pesticide as possible, using a dry cloth if water is not available. SEE A DOCTOR if serious.

■ Repeated exposure - If using toxic chemicals often have a medical examination and appropriate tests to detect if exposure has gone beyond safe limits.

SPRAYER CHOICE AND MAINTENANCE

Herbicide application equipment should ensure a uniform distribution of an exact quantity of pesticide in a given area and save the farmer time and effort.

Choice of a Sprayer

The choice of a sprayer will depend on the size of the area to be treated, the nature of the land, the availability of water, and sprayer cost. Versatility, or the ability to spray several types of pesticides under several types of conditions, is a major consideration when choosing a sprayer. Sound construction, ease of operation, cleaning and maintenance, availability of spare parts are additional considerations. Make certain that parts are resistant to rust and corrosion.

Knapsack sprayers are more suitable than tractor equipment on small farms and in hilly areas, but where water supplies are limited, the spinning disc sprayers are preferred.

Types of Spraying Equipment

1. Hand operated machines

■ Syringe sprayer - This is small syringe-type sprayer, or pistol-grip sprayer, is suitable for spot treatment. A marker dye such as methylene blue or lissamine scarlet may be added to the spray in order to see which areas have been treated.
Compression sprayers - Shoulder slung or knapsack compression sprayers have a tank which is filled two-thirds full with the spray mixture. The lid is replaced tightly and the tank is pumped up with air until the desired pressure (400 kPa or 4 bar) is reached. The operator then directs the nozzle and releases the liquid as a spray. After air under pressure runs out, the operator then has to repressurize. It is difficult to maintain a constant pressure and therefore, the output changes slightly as the pressure drops while spraying. A regulating valve can help to warn the operator when the pressure needs increasing by further pumping. In most cases, there is no agitation system except by shaking the tank. Usually application is slow because the tank must be refilled and repressurized many times, depending on the size of the area to be sprayed.

Lever operated knapsack sprayers - These are the most common sprayers. They may be more expensive than compression sprayers. Piston or diaphragm pumps are operated by an underarm pumping lever. Pressure is maintained by constant manual pumping. There may be a choice of pressure setting in the compression chamber which makes the sprayer more versatile for spraying different types of pesticides. These sprayers are useful for applying herbicides to relatively small areas, for spot spraying, and for directed applications.

2. Spinning disc sprayers

In this type of applicator electricity or air spins a serrated disc which breaks the liquid spray solution into droplets. The electric powered type is usually run by batteries. Having a consistent battery supply is often a problem in developing countries; however, there are now solar batteries available which may help to solve this problem. If using this type, the machine should have a motor where the speed is constant. The sprayer models using air pumps for power overcome the battery problem.

This type of applicator is useful for spraying low volumes of water, or where water availability is an over-riding problem. The sprayers are difficult to calibrate and it is difficult to see the swath width where you have sprayed. There is a variation in the spray deposit that is similar to the pattern given from a cone nozzle, which is not ideal. Do not use spinning disc sprayers that produce very small droplets. These are useful for spraying insecticides or fungicides, but are not useful for herbicide spraying because there is greater chance of drift away from the target.
3. **Power operated sprayers**

These sprayers are usually used for large scale farming and are mounted on a tractor or trailer. The pumps are usually driven by a power take-off from the tractor. The tank should be large enough so that frequent refills are avoided but not so large that it compacts the soil. The system should have a method to agitate the spray solution. This is necessary when spraying wettable powders. It is also very important that the system have a pressure regulating valve to avoid excessive pressure. Uniform application depends on a constant forward speed and pressure.

4. **Direct contact applicators**

These applicators use a rope or sponge which becomes saturated with the herbicide solution and transfers it directly onto the weed. The rope wick applicator can be attached to a tractor or handheld. The handheld applicator is extremely useful for spot applications or treating small areas of weeds with systemic type herbicides such as glyphosate. It can also be used to selectively treat weeds which are growing above the crop canopy. Obviously, this method is more useful for taller weed species in short statured crops. In this instance, crop loss has most likely taken place, but harvest interference and weed seeding can be prevented. Wetting a small area of the top part of the weed is sufficient to kill it. The rope must not become dry.

5. **Granule applicators**

Granules can be applied by hand or from simple containers with holes but the distribution tends to be uneven. Special granule applicators have a metering device which ensures even dispersal. Do not adjust the meters with granules inside as it will jam the machine. These applicators can be manual or machine run.

**Nozzles**

1. **Regular flat fan nozzles**

These are commonly used for most broadcast spraying of herbicides and for certain insecticides. They produce a spray pattern with tapered edges in a flat fan shape. If using a number of them on a boom, a spacing of 40-60 cm apart and 25-50 cm above the target is recommended. The spray patterns of the nozzles with a tapered spray pattern should overlap about 50% for even spray distribution. These nozzles come with different spray angles. Eighty (80) degree nozzles are most common.
2. Even flat fan or band spraying nozzles

These nozzles are similar to the regular flat fan type except that they have a uniform spray pattern; they do not produce patterns with tapered edges. They are used for banding pre-emergence herbicides over the crop row. They should not be used for broadcast spraying because overlap will result in twice the amount of herbicide delivered where they overlap. Also many angles and sizes are manufactured.

3. Flood jet or impact tip nozzles

This nozzle is constructed so that as the liquid leaves the circular hole (orifice), strikes a flat surface, deflects, and forms a flat liquid sheet, similar to the flat fan shape. The CP (Cooper Pegler) sprayers are usually sold with this type of nozzle called a 'Polijet'. It can be operated at a relatively low pressure, which is useful to reduce drift. The pressure setting can affect the width of the spray pattern. The distribution pattern is usually not as uniform as with the other types of flat fan nozzles. The red-colored nozzle produces a swath width of 2.0 m, the blue nozzle 1.5 m, the green nozzle 1.0 m, and the yellow nozzle 0.5 m (useful for spot spraying).

4. Cone nozzles

These nozzles have a small chamber where the liquid is whirled around, then emerges as a conical sheet with a hollow or full center. These nozzles are generally used at higher pressures and produce smaller droplets. They are most often used for insecticide and fungicide spraying.

If there is a choice in nozzle selection the following recommendations are made for herbicide application:

- Soil applied:
  - For broadcast spraying use a flood jet nozzle.
  - For band spraying use an even flat fan nozzle.

- Foliar applied:
  - For systemic and translocated not requiring thorough coverage, use a flood jet nozzle.
  - To avoid spray drift use a regular flat fan nozzle.
  - For thorough coverage use a regular flat fan nozzle, or as a second choice a flood jet.
Figure 6. Spray patterns from two nozzle types.
Sprayer maintenance

1. Cleaning the sprayer after use

Wash the sprayer out after each use several times with clean water. This avoids corrosion as well as contamination of the next crop to be sprayed. Make sure that the nozzles and screens are clean. If the sprayer is to be stored, wash with detergent and rinse several times to remove the detergent. Drain the tank and leave it with the lid off to allow the air to circulate. To remove hormonal herbicide residues, wash out with a 1% ammonia solution. Then rinse out thoroughly with water.

2. Check equipment regularly

Check for leaking hoses and gaskets especially where the parts are joined together. Check nozzles for wear and to make sure they are not plugged. If they are blocked, do not clean them using a hard object. This could damage the orifice.

SPRAVER CALIBRATION

The purpose of calibration is to determine or adjust the sprayer's output (amount of liquid spraying out), expressed in liters per hectare. This information is used to make certain that an exact amount of chemical that is mixed in the water is uniformly applied over a measured area.

- An excessive amount of herbicide can kill or injure the crop, cost extra money, or leave undesirable residues in the soil.
- Too little herbicide results in poor weed control.

The following discussion will concentrate on the calibration of a knapsack sprayer, one of the most common types of sprayers used in Ethiopia. The principles are the same for all other hand and power operated sprayers.

Facts Affecting the Rates of Application

1. Nozzle orifice size

The larger the size of the hole, the greater the output.

2. Pressure

An increase in pressure will increase the output. The pressure is also a function of how hard the operator pumps.
The harder he pumps the greater the pressure until the maximum pressure is reached.

3. **Spray swath width**

This is determined by the type of nozzle, the number of nozzles on the spray boom, and the height the boom is held above the ground or weeds. The greater the height above the ground, the greater the swath width and the greater the chance of drift.

4. **Walking speed**

The faster the speed, the lower the dosage delivered to the area.

**Before Calibration Check that the Sprayer is Working Properly**

1. Check for leaks. Make sure that hose and boom connections are tight. Look underneath at the base of the diaphragm when the sprayer has water in it to make sure it is not leaking.

2. Check that the nozzles are giving uniform spray pattern and are not blocked or worn.

3. Check that the pressure setting is correct. For herbicide spraying, the pressure should be set on 'L' for low. Delivery should be between 200 and 300 liters/ha with the CP sprayers when set on L.

4. Check that the sprayer and its three screens (handle, nozzle, water loading) are clean.

5. Check that the boom handle is adjusted to the correct position (trigger down is most comfortable); and the trigger handle shuts on and off without sticking.

6. Check that the nozzle is adjusted to the correct position, spraying down and out in front of you. When spraying hold it to the side of you.

7. Check that the pump handle is in the correct position, so that it is pointing forward and on the side comfortable for you.

**Calibration Method**

1. Adjusting nozzle, pump pressure, spray width, and walking speed.
Select a practice area of a field which is similar in condition to the field where you are going to spray.

Select the nozzle you are going to use. It is recommended that a red colored Polijet flood jet nozzle be used when using the CP sprayer. This gives a 2-meter spray swath width when held 50 cm above ground level or top of foliage. The flood jet which produces a flat fan shape is the correct type of nozzle to use to spray herbicides. This is different from the cone nozzles used for insecticide and fungicide spraying.

Install the nozzle and set the pressure on L for a CP sprayer or on a lower pressure setting for other sprayers.

Fill the sprayer with some water and practice walking and pumping and holding the boom at 50 cm, approximately at knee height for spraying across bare soil. If there are weeds and crop present, hold the boom approximately 50 cm above the top of the weeds to get the desired 2 meter swath width (see 5 below).

Check the boom height by standing still and spraying. Measure the distance from one side of the spray pattern to the other. This is the swath width, or the width of one spraying strip. Compare this distance with the 2 meters for the red nozzle. Raise your boom if your swath width is too narrow. Lower the boom if your swath width is too wide.

Once you feel comfortable with the sprayer and have it properly adjusted, practice your walking speed with water in the tank in conditions similar to where you will spray. Train yourself to walk at one meter per second. In other words, you should cover 20 meters in 20 seconds. Measure a strip and have someone else time your speed while you practice. Practice enough times so that your speed is constant over several tries. You should develop a pumping and walking rhythm which you should be able to remember.

2. Determining output (liters per ha)

Add water (at least 5 liters) to the completely empty sprayer. Fill the sprayer up to line of the measuring marks located on the side.

Walking at one meter per second, spray a measured area which equals the total plot area to be sprayed. Record the time required to spray the measured area to check on
your walking speed. (If you have to stop in order to return, do not record your stopping time, only the actual spray time.) For example, if you are spraying a plot which is 2 m x 24 m (2 m x 24 m = 48 m), you should take a total of 24 seconds to spray the strip when using the red nozzle, and hence the plot area.

To see how much water was used, measure the water needed to refill the sprayer to the original level. This quantity is what you sprayed out and is the amount of water needed to cover the area you just sprayed.

3. Repeat above steps several times to check for accuracy. Take the average amount of water used.

To cross-check the output calculated in the steps above, you can also operate the sprayer in a stationary position at the same pressure (pumping speed) for the same time required to cover the measured area. Collect and measure the output from the nozzle in a container. This amount should equal the amount of water you used to refill the sprayer to its original level.

4. Calculate output in liters per hectare. Use the following formula:

\[
\text{liters/ha} = \frac{\text{water used (liters) to spray test area} \times 10,000 \, \text{m}^2}{\text{area sprayed in m}^2}
\]

*Example - Test area measured 400 m² (swath width = 2 m, plot length = 200 m)

\[
6 \text{ liters} \times 10,000 \, \text{m}^2 = 150 \text{ liters/ha (output)} \quad \frac{400 \, \text{m}^2}{\text{400 m}^2}
\]

Note: 10,000 m² = one hectare

5. Things to check while calculating output

- Was a steady pace maintained while pumping and walking?
- Did the spray times differ much? Was the variation acceptable?
- Was the boom held at a constant height?
Were there any changes in output due to blockages in the system? If so, immediately check for dirty screens, blocked nozzles. Clean the screens and blow and rinse the nozzle to clear it. Do not clean it with hard objects or put the nozzle into your mouth.

**IMPORTANT**—Every time you use a sprayer, you should calibrate it again. If you change and use a different person to spray, you should calibrate the sprayer for the new person. It is not safe to assume that the output will always be constant.

6. **Determining the amount of water needed for different sized areas**

- If the area is greater than 1 ha:

  \[
  \text{Total water} = \text{number of hectares} \times \text{output (liter/ha)}
  \]

  *Example: 1.7 ha x 150 liters/ha = 255 liters water

  \[
  \text{Number of sprayer} = \frac{\text{total volume water needed}}{\text{volume of sprayer}}
  \]

  *Example: sprayer volume = 15 liters
  To spray 255 liters you need 17 sprayer loads (255/15)

- Output determination when spraying small plots (e.g. trials or small demonstrations):

  - If area is less than 1 ha then calculate the water needed using either of these two methods:

  (1) If you know the output then calculate using the following formula:

  \[
  \text{water} = \frac{\text{area to be sprayed} \times \text{output (liters/ha)}}{10,000 \text{ m}^2}
  \]

  *Example: 8,000 m² x 150 l/ha = 120 liters water

  (2) If you do not know the sprayer output, measure out the plot area and spray it. Determine the amount of water
you used to spray the plot by refilling the sprayer to
the original level or by spraying into a container for
the same amount of time it took you to spray the plot and
measure this water.

You now have the amount of water needed to cover the plot
area you are going to spray.

Remember: When you are spraying, the walking speed, nozzle
size, and pump pressure (pumping speed) must remain constant
and the same as was used in the calibration. If any of these
factors change, then the output will change and the
pesticide will not be applied correctly.

HERBICIDE CALCULATIONS

Procedure Summarized

1. Determine output (liters/ha) from sprayer calibration.

2. Determine the total size of area to be sprayed.

3. Calculate total amount of water needed to spray the
entire area. Calculate the number of sprayer loads which are
needed if the area is large.

4. Determine amount of herbicide product needed to treat one
hectare.

□ Read the label or use recommendations to determine the
product amount.

OR

□ Use the amount of active ingredient (ai) recommended per
hectare to calculate the amount of product needed to
treat your area.

Note: The active ingredient (ai) or the actual technical
material (pesticide) is only one ingredient in the
commercial product. Other ingredients are inert and are
used as carriers, solvents, or to make the chemical work
better.

"ai" is usually expressed as g/kg or g per liter or in
percentage (%).

*Example: Name on label: Gesaprim (500g per liter FW)

Active ingredient: atrazine 50%
Inert ingredients: 50%
5. Calculate how much herbicide must be put into each sprayer load if the area is large and requires more than one sprayer load.

Calculations and Examples

1. Water: (Review sprayer calibration)

2. Herbicide:

- Determine the amount of commercial product (what you pour or measure out of the commercial container) needed for the size of area you want to treat and which will be put into the calculated amount of water.

- If the amount of commercial product is known, then:

\[
\text{area to be treated} = \frac{\text{amount herbicide needed}}{10,000 \text{ m}^2} \times \text{amount herbicide per ha}
\]

*Example: You want to treat an area which is 400 m\(^2\) with 2 kg/ha commercial product. How much herbicide should you use?

\[
\begin{align*}
400 \text{ m}^2 &= \frac{\text{amount herbicide needed}}{10,000 \text{ m}^2} \\
2 \text{ kg/ha} &= \frac{\text{amount herbicide needed}}{10,000 \text{ m}^2} \\
\frac{400}{10,000} &= \frac{\text{amount herbicide needed}}{10,000} \\
0.08 &= \frac{\text{amount herbicide needed}}{10,000} \\
\text{amount herbicide needed} &= 0.08 \times 10,000 = 800 \text{ g}
\end{align*}
\]

- If the amount of active ingredient per ha is known, then:

\[
\begin{align*}
(1) \text{rate (ai) recommended} &= \frac{\text{'x' amount ai for plot}}{10,000 \text{ m}^2} \\
\text{(2) 'x' amount g ai} &= \frac{\text{product needed}}{\text{ai}}
\end{align*}
\]

percent ai is expressed as a decimal in the equation, 50\% = \frac{50}{100} = 0.50

*Example: Assume we want to apply 1.5 kg active ingredient per ha of a product containing 50\% of the active ingredient to a plot measuring 2 m \times 24 m. How much commercial product do we need to add to the sprayer?
(1) 1.5 kg ai/ha = 'x' kg ai for plot area
\[
\frac{1.5 \text{ kg ai/ha}}{10,000 \text{ m}^2} = \frac{\text{'x' kg ai}}{48 \text{ m}^2}
\]
'x' = 0.0072 kg ai for plot area (48 m²) = 7.2 g ai

(2) 7.2 g ai = 14.4 g product for 48 m²

*Example:

(1) Assume we want to apply 2.0 kg ai/ha of a product containing 80% of the active ingredient to 0.7 ha. How much commercial product will be needed?

(a) 2.0 kg ai = 'x' kg ai
\[
\frac{2.0 \text{ kg ai}}{1 \text{ ha}} = \frac{\text{'x' kg ai}}{0.7 \text{ ha}}
\]
'x' = 1.4 kg ai

(b) 1.4 kg ai = 1.75 kg product needed
\[
\frac{1.4 \text{ kg ai}}{0.80} = \frac{1.75 \text{ kg product needed}}{}
\]

(2) How many times will a CP15 sprayer have to be filled if the sprayer output is 150 liters/ha to spray the 0.7 ha? How much product should be added each time the sprayer is filled?

\[
\frac{150 \text{ liters}}{1 \text{ ha}} = \frac{\text{'x' liters}}{0.7 \text{ ha}}
\]

'x' = 105 liters to spray 0.7 ha

Each CP sprayer holds 15 liters. Therefore, 105 liters require 8 tanks full. 105/15 = 7

■ The above method will work for all liquids, powders, granules, etc. However, whenever the product is expressed in acid equivalents (ae) then you must use 'ae' rather than 'ai' to do the calculations. Sometimes, both 'ai' and 'ae' will be present on the label. In this case, use 'ae' to do the calculations.

*Example: 2,4-D ester
Active ingredients:
2,4 dichlorophenoxyacetic acid,
butoxyethanol ester 63.2%

Inert ingredients:
63.2%
38.8%
100.0%
Contains 2,4 dichlorophenoxyacetic acid, equivalent to 43.5\% by weight or 480 g ae/liter.

In this case, you use 480 g ae/liter for your calculations. This would be the same as 48\% ae.

Do not let this confuse you. If 'ai' is used in the above calculations, you will underestimate the amount of herbicide needed. Products which may be expressed in 'ae' are: 2,4-D; MCPA; glyphosate; among others. Use 'ae' in the same way 'ai' is used in the above examples.

TIME OF APPLICATION

Generally the terms used for the time of application refer to the stage of planting or emergence of the crop. Sometimes however, reference is also made to the stage of the weeds.

Pre-sowing or Pre-transplanting

These applications are made before the crop is planted. They can be soil-applied herbicides or applied to the foliage of the weeds that are already emerged. The term pre-plant incorporated or 'PPI' refers to those chemicals which are applied to the soil before the crop is planted and which are incorporated or mixed into the soil. This must be done for volatile herbicides such as EPTC or butylate, for example, or for herbicides which do not readily move in the soil solution such as trifluralin. Herbicides applied PPI, that is requiring incorporation, are not usually recommended for small farmers because they do not have suitable machinery to do the job. Heavier equipment such as disks, harrows, or rotary hoes used at a relatively fast but even speed, not achievable by animal power, are required to mix the herbicides into the soil.

Pre-emergence

These applications are made after the crop is planted but before it emerges. This includes both soil- and foliar-applied herbicides, because the application can be made to germinating weeds, soon to be germinating weeds, and emerged weeds. In the case of emerged weeds, the herbicide is applied pre-emergence to the crop but post-emergence to the weeds.

Post-emergence

These applications are made after the crop has emerged. This timing can also be for both soil and foliar applied materials. However, weeds have usually emerged at the time
Pre-emergence
To the crop and the weeds

Post-emergence
To the crop and the weeds

To the crop
Directed Post-emergence

Crop emerged, weeds not emerged

Crop and weeds emerged

Pre-emergence

Band Application for Row Seeded Crops

Key

0 Crop seed

# Weed seed

Figure 7. Timing and placement of herbicide applications
that these herbicides are applied. If they have not emerged, then the herbicide will be applied post-emergence to the crop but pre-emergence to the weeds.

See Figure 7 in order to make the application times understood. So that there is no confusion, state the application time in relation to both the crop and the weeds.

HERBICIDE PLACEMENT

Broadcast

This is the most common method of application. The herbicide is sprayed to cover the entire area. It is a useful method in broadcast-seeded crops. Both soil- and foliar-applied herbicides can be sprayed pre-plant, pre-emergence or post-emergence in the broadcast-seeded crops.

Band Application

The herbicide is applied only to a portion of the field, usually in a band directly over the crop row. Banding can be considered as a type of directed application. It is also possible to apply the band only between the crop rows; however, this is usually called directed sprays (see below). To use band application, the crop has to be planted in rows. Both soil- and foliar-applied herbicides can be applied in this manner at pre-plant, pre-emergence, or post-emergence timings, but pre-emergence is the most common time of banding the herbicide. Economics is the primary reason for using this placement method because the total amount of herbicide needed is reduced. This method can be combined with other weed control measures which will be used in the non-herbicide strips. Banding is also useful where a tolerant crop is being followed by a susceptible crop. This usage requires more precision when applying the herbicide to avoid any phytotoxicity problems.

Directed Sprays

These are usually applied to soil or weeds between crop rows. They can be applied pre- or post-emergence. Special application equipment such as shields or special nozzles are used to keep the spray off the crop when applied post-emergence in particular. Non-selective herbicides are applied in this fashion in perennial crops such as coffee.

Spot sprays

This is a very localized form of directed spray. Only
selected areas of the field which are infested with a problematic weed are treated. This is more economical than broadcast application in situations where the infestation is patchy. The 'weed wiper' a simple tool which 'wipes' the herbicide solution on the weed is useful for the spot application of some translocated herbicides.

REFERENCES

The following references were used in writing Chapter I and can be found in Annex 8: 3, 4, 7, 8, 12, 22, 24, 28, 38, 41, 42, 45.
Chapter II

Problem Identification and Solutions
Weed Problem Identification

IS THERE A PROBLEM?

Farmers' View

Case I  The farmer accepts weeds as they occur and does not think they are a problem.

Case II The farmer recognizes weeds as being undesirable but does nothing to control them; he may move away from the area.

Case III The farmer recognizes weeds are a problem and attempts to control them, but in a limited and ineffective way.

Case IV The farmer recognizes weeds are a problem and tries to control them as effectively as possible.

Being able to identify weeds and to know their growth characteristics can help the extension worker to identify problems.

In Case I, if there is a problem, the farmer must first be convinced in order for him to want to take action. The Case I farmer may have reasons for not controlling the weeds; for example, perhaps the weeds are used for dry season animal feed. It is important to understand why the farmer is doing what he is doing in all cases. Case II and possibly Case III farmers present a challenge to extension workers as they have limited resources to work with to control problem weeds. In Case II, the unweeded crop may be of low priority.

In Case III, they may not be able to weed because of labor problems, lack of animals, environmental problems, etc. Changes in cultural practices may be the only feasible solution. Case IV farmers offer the best opportunity for change because they usually have the resources to devote to solving the problem.

Extensionists View

Identify and focus on the most apparent, serious weed problems where control should produce benefits. In order to both identify the problem and offer realistic control options to the farmer, the extension worker must be able to identify the weeds and know about their life cycle. For example, controlling a perennial grass which has extensive underground rhizomes requires a different strategy than to controlling an annual broadleaf weed.
WEED IDENTIFICATION

Farmers, extension workers, and researchers cannot apply the correct control measures or prioritize where they should put their limited weed control resources unless they can identify the species correctly and decide whether they are a severe or moderate problem. At the very least, they should know whether the weed is annual or perennial and if it is a grass, broadleaf, or sedge species. Most farmers can point out the weeds that they find most problematic and tell you why they are problems.

By identifying weeds in one season, problems can be anticipated and control measures planned for the next season. It is also important to identify and anticipate the spread of noxious weed species which may not be in abundance now, but could be in the future.

Proper use and choice of herbicides is dependent on knowing what weed species are problems in the various crops.

Wild plants that occur on field edges or in minor amounts within the crop field are not considered weeds. They do not pose any danger in terms of reducing crop yield, poisoning animals, etc. It is important to be able to not only identify the species but also know their significance.

Weed recognition is learned through experience. It is important to be able to have aids: special publications on weed identification for your area, a herbarium, or a specialist who can help verify the identification.

WEED SPECIES SURVEY

Purpose

Surveys can give new information about an area; provide baseline data; check on the accuracy of previous survey data; identify changes over time; link local weed names to scientific names; and in building a reference collection of weed species. The main point is to get a good indication of the problems. It is not necessary to get exact counts of the various weed species from each area.

Types

Surveys of weed problems can be of two general types: 1) 'regional' where general, wide spread problems are identified as well as small but serious problems; 2) a 'farm field' survey which indicates specific problems associated with certain fields within a smaller area.
1. Regional survey

- Consider environmental variation such as altitude, soils, rainfall, and temperature.
- Consider farming system variation, by crops and cropping patterns, as well as by differences in farm size and resources.
- Make a preliminary map, if possible, to subdivide the area into different zones based on the above characteristics. This can be modified later when there is more information.
- Drive through the area in as many different ways as possible and sample and/or observe about every 5 kms or less frequently if the area is large. Collect, label, and press weed specimens, take photographs if you have a camera, make notes on the areas as you pass through. If there is time, interview key informants, e.g., farmers, local extension workers, village heads, etc.

2. Farm field

This type of survey is sampling a much smaller area than the regional survey. It may be a single field that you are interested in or several fields in an area. Collect some background information concerning the farm from the farmer on crops grown, how he is growing them, last year's crops, etc. (See next section for detailed questions to ask).

Methods

1) Line survey - This method commonly used by foresters, uses a random stretched line (rope or string) with markers at intervals. At these points note the weed problems. This method is time consuming and not recommended for most surveys.

2) Quadrat survey - A 0.5 m square is thrown randomly, taking several samples from each field. The greater the apparent variability in the weed cover, the more samples are needed. Weeds inside the square are identified, counted, rated and percent cover estimated. This sampling method is useful for research work where precise numbers are needed; however, for a general weed survey it is too time consuming and the information is too detailed.

3) Subjective survey - When walking transects across the field in several directions note the growth stage of the weed species, distribution (whether even, in clumps, only
on field edges, etc.), and frequency of occurrence. Generally, the more numerous and widely dispersed a species is, the more serious a problem it is. There are exceptions however, a clump of Striga, a parasitic weed, is a serious problem because even in small amounts it is very difficult to control; therefore, it is important that you know about the weed's biology and its 'weedy' potential. Look at the potential problems in neighboring fields and in the surrounding area to get an idea of the spread of serious weeds. 'Weeds' on the edge of the field may not necessarily be weeds.

- Ranking systems

Because counting is very time consuming, it is recommended that a visual assessment using a subjective ranking system be used to estimate density and distribution. Any simple numerical system can be adopted as long as it is defined. An example is: 0 = no weeds; 1 = rare or scarce; 2 = occassional; 3 = common; 4 = abundant. If more than one person is involved in the survey, make sure you agree on what is meant by these terms. The frequency of occurrence can be illustrated from the data using a histogram. Averages of the numbers cannot be taken. Give a score for each of the main weed species. If you do not know their names, mark them according to whether they are annuals, perennials and grasses, broadleafs, or sedges. (See Figure 8.)

- Timing of the survey

Weed germination occurs at different times throughout the season; therefore, the area under surveillance should be visited several times during the growing season if possible.

There will be some year-to-year variation due to weather differences, changes in cultural practices, weed population shifts, and newly introduced species.

FARMING SYSTEMS SURVEYS

Purpose

Most production practices influence weed species and their density. It is therefore very important to understand what the farmer is doing on his farm and why. A farming systems survey is a technique that helps understand the environment, production processes, and decision-making behavior used by small farmers. Understanding these factors assists extensionists and researchers to determine the relevance,
Quadrat Survey

Square frame (0.5m sq.) is randomly thrown in the field a number of times. Weed species inside the frame are counted and noted.

Line Survey

Rope or string with markers stretched randomly 3-4 times across the field. Species under each marker are noted and counted.
A rating system is defined in order to subjectively rank the weeds as to their importance and occurrence. An example is:

- 0 = none
- 1 = rare, scarce
- 2 = occasional
- 3 = common
- 4 = abundant

Weeds rated as follows:

<table>
<thead>
<tr>
<th>Species</th>
<th>Rating score</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>■</td>
<td>3</td>
</tr>
<tr>
<td>▼</td>
<td>3</td>
</tr>
<tr>
<td>○</td>
<td>1</td>
</tr>
<tr>
<td>★</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 8. Weed survey techniques for a farmer's field.
practicality and potential success of any innovation or recommendation. In order to recommend practical solutions to the farmer's weed problems, information about his available resources is necessary because what the farmer can actually do or how he can actually change current practices is limited by his resources.

This methodology can provide new information and baseline data, check the accuracy of past assumptions, identify changes, and assist in prioritizing areas of concentration for extension and research.

Definition

A specific farming system arises from the decisions taken by a farming family which allocate different quantities of land, labor, capital, and management to crop, livestock, and off-farm enterprises in a manner which will, to the best of the family's ability, maximize the returns suitable to their needs.

The farming systems approach examines a full range of household activities, including livestock production, off-farm enterprises and domestic tasks, and the interactions among them, rather than studying only cropping activities within the farm operation (after Gilbert, et al, 1980).

Understanding the System

1. In order to understand 'Why is the farmer doing what he is doing?', we need answers to some questions:

   ■ What are the physical resource limitations affecting the farmer's decisions?

   ■ How diverse is the area and how does it affect the farmer's decisions?

   ■ What are the economic factors such as off-farm income, credit accessibility, labor availability, land management, etc., which influence the farmer's decisions?

   ■ What are the farmer attitudes: taste preferences governing choice of varieties; strategies to achieve stability, to avoid risk, and to balance food and cash crop production?

2. Specific points to consider when surveying weed management problems in order to identify solutions to test or extend.
Resources

Timely labor availability (people and/or animals) is usually one of the crucial limiting factors for weed control. It is important to understand how farm families decide: who should weed, when to weed, what crop to weed first, etc.

Labor allocation to other activities must be understood in order to recommend workable solutions both before and during the growing season.

The amount of land under cultivation may reflect weed management problems. A weed management solution may help farmers to increase acreage under cultivation. This change in decision may change allocation of labor and other management factors.

Understand cash or credit availability when suggesting purchase of inputs, such as herbicides, labor, and equipment.

Understand crop-livestock interactions

Attitudes towards using oxen or other animals for mechanical weeding.

Use of weeds to supplement animal feed.

Grazing habits that may affect weed distribution, availability of animal power, etc.

Animal health in relation to land preparation and weeding efficiency.

Understand crop husbandry management decisions

Reasons for present land preparation and planting methods used.

Reasons for crop combinations and population densities and spacings used.

Reasons for crop species and varieties used.

Reasons for the existing crop rotation schedule followed, if any, and the flexibility that may exist within the system.

Current water and fertility management schedules followed now and implications of change on weed problems.
The level of sophistication of the farmer's management. Could his labor force adopt the use of herbicides if trained?

The answers to these questions will influence your choice of innovation to solve the weed management problems. Try to understand the present system and the flexibility in that system for change. A more detailed sample questionnaire including a labor profile data sheet is presented in the Annex.

Types of Farming Systems Surveys

1. **Informal or exploratory survey**

This type of survey does not use a questionnaire to collect information, but instead is based on information collected by making observations on the farm activities and by discussions with farmers. This type of survey is relatively fast and can provide a lot of information. It does not have to be statistically analyzed. It usually gives sufficient information on which to make plans concerning trials or demonstrations. It is usually done to assist in the design of a formal survey.

The major objective is to understand the farmers general farming practices, and more specifically to understand their weed problems and what farm practices or control difficulties are contributing toward the problems.

- **In summary, the objectives are to:**

  Understand what the farmers are doing and why, identify problems and constraints, prioritize problems and identify possible solutions, and provide inputs for a formal survey.

- **Steps:**

  1. Choose the survey area. Do not make it too large. Define and focus on recommendation domains or target groups. Do only one homogenous zone at a time, e.g., Wolnadega areas of a woreda. It can be 4-5 PAs in 1 woreda. You can always expand to other areas later.

  2. After knowing some information about the area, you can design guidelines containing a check list of topics that you want to cover when you are interviewing the farmer. This set of questions is only a guide. It can be changed or altered depending on what information you need to collect.
3. Be sure to get this activity approved by the necessary authorities in the survey area and that the objectives are well understood by these people as well as by the people interviewed.

4. Choose farmers who seem to be representative in the area that you are surveying. If you are looking at a specific weed problem, such as Striga, you will obviously want to choose farmers who have that particular problem. Try to interview the person who actually makes the decisions about the farm work as well as those who do the work if they are different people from the decision makers.

5. Make the interview a reasonable length of time. Between thirty minutes to one hour is good. You do not have to discuss all the areas on your guideline with each farmer, but you can discuss parts with various farmers. You are trying to build up an average picture of what is going on in the homogenous zone you have chosen. It does not initially have to be detailed for each farmer.

6. Make sure you not only interview the farmer but also look around his farm to help you verify some of his answers. You may see things which you want to ask about which were not originally on your guidelines but which are important.

7. Try to have a smooth discussion with the farmer. Make him feel like you are having a conversation rather than a question and answer period. That is, mix questions with comments. If the farmer wants to spend time talking about an issue that is important to him, let him continue for a reasonable amount of time. Try to keep the conversation centered as much as possible on the points that you are interested in.

8. Avoid sensitive questions, such as how many cattle he owns, how much money did he make, etc., at first. Once the farmer feels more confident with you and not suspicious, then you can ask some sensitive questions.

9. Be sensitive about the farmers schedule. Try not to inconvenience him. Thank him for discussing with you when you finish.

10. Be aware of the language that the farmer speaks. It may be necessary to use a translator.

11. You need to record the responses. This can be done just after the interview if you think you can remember
the answers. If not, you can bring a 'secretary' to help you or take a few notes yourself in the process of the interview. Try not to make the time spent on writing too excessive as this will distract the farmer.

12. To assist in note taking organization, it is recommended that the guidelines be divided into major subject matter areas. The guidelines are usually organized in such a way that the areas concerning various farm practices come in the same sequence as you would actually do them during the cropping season. For example:

--General information: questions concerning farm size, crops grown, areas devoted to each crop; labor availability for various farm jobs; number of oxen owned or available for farm work; etc.

--Crop choice, crop rotation, fallowing, etc.

--Land preparation information

--Planting methods, populations and spacing chosen, variety choice, fertilizing, seed incorporation methods

--Pest control and crop husbandry practices such as thinning

--Weeding practices

--Specific weed problems and reasons

--Farmer's attitudes about decision making, new technologies

--Other problems faced, for example, marketing

--Resource limitations: specific times of labor shortages, cash flow problems, etc.

13. A set of notes should be produced which have corresponding numbers and sections to the topics or questions in the guidelines. These notes can be compiled and summarized daily while the survey is in process. This will help you to re-evaluate your guidelines and to sort out areas which need further concentration or clarification.

2. Formal survey

For this type of survey, a questionnaire is designed to be filled out by the interviewer. A random sample of farmers is
chosen from the survey area. Enumerators are often trained to carry out the interview process. The answers are tabulated and can be statistically analyzed. This type of survey takes much more time and effort to complete than an informal survey.

- The major objectives are to:
  
  verify certain information which was collected in the informal survey, collect additional information after the informal survey, and quantify a variety of responses to see how many farmers fit into various categories.

- The procedure is to:
  1. Design the questionnaire.
  2. Translate it into the local language or Amharic if necessary.
  3. Set up a sampling procedure.
  4. Select and train the enumerators.
  5. Field test the questionnaire and then revise it.
  6. Implement the survey.
  7. Analyze and interpret the results.

Recommendation Domains or Target Groups

"A domain is a group of farmers who will adopt the same recommendation given equal access to information; or a group of farmers whose circumstances are similar enough so that the same recommendations are applicable. In practice, domains include farmers with similar production practices, who share similar opportunities for development, who have similar resources and for whom the same research and development efforts are most likely to be relevant." (Anandajayasekeram, 1985)

There may be different recommendation domains or groups of farmers based on weed problems or resources available to solve weed problems. The main objective is to group the farmers who use similar production practices and who have similar problems. The extension agent must decide on recommendation domains by knowing the area and farmers where he works. Ultimately, using this concept should make the extension work easier and the recommendations more relevant to problem solution.
Choosing Areas and Farmers for Interviews

1. Choosing areas

- Homogeneous means areas which are the same or have the same major characteristics.

- A multistage sampling technique can be used based on administrative divisions. For example, a particular area may be selected because it is homogenous. Within this area several woredas may be chosen and within these woredas, several Peasant Associations (PA) may be selected. Within any given PA, a selection of individual farmers or farmers cooperatives may be chosen (See Figure 10).

- A multistage sample may be taken but clustered for logistic reasons using agroecological zones as a basis (See Figure 9).

2. Choosing farmers for interviews

- The sample size depends upon various factors:
  -- variability in the area (greater the variability the larger the sample)
  -- degree of precision wanted (greater the precision needed, the larger the sample)
  -- the data handling facility
  -- logistics
  -- nature of the problem being investigated

- Farmers should be selected who are representative of the population, e.g., have representative income levels and resource levels.

EXPERIMENTATION

Loss assessment trials can be used to evaluate and quantify losses due to weeds. Trials can assist in ranking the importance of problems. They can be used to investigate the causes of problems.

A simple trial can be repeated at several sites in the crop of interest within each distinctive farming system. The trial should include at the minimum the following treatments: no weeding, complete weed free but avoid crop
Figure 9. Diagram of multistage sampling using agroecological boundaries and clustering for better logistics.
Figure 10: Diagram of multistage sampling using political boundaries
injury from late weeding, a recommended practice, and the farmer's practice. No weeding is included only where this sort of information is useful. In areas where the farmer always weed, do not include this treatment.

If possible the trial should be done on the farmer's field so that a sample from his plot can be taken. Farmer's fields tend to be more representative of the weed problem and the farmer's practice because he is doing it. Be sure to fully describe each farmer's practices because they will differ from farm to farm. The reason to include the farmer's practice is to be able to estimate what yield loss is actually occurring within a range of farms in the crop you are working in.

A loss assessment trial may be done on a research station or trial site but this will not adequately sample the environments, varying field histories, weed species variation, etc., found in the farmer's environment. It will give a general indication of percentage loss due to weeds, which may be useful in general terms, to discuss the impact of weeds on production compared to other pests or production problems. This may help to set priorities for concentrating extension as well as research activities.

FIELD SAMPLING

- Collect representative yield samples from selected farmers' fields. A 1 x 1 m sample from a representative area should be sufficient. This size will vary with the type of crop. The number of fields to be sampled will also vary depending upon the variability in the situation.

- If possible, select the sample sites at the beginning of the growing season. Mark the area with stakes or string.

- Observe and write down how the area is treated during the season so that data collected can be interpreted. For example, the sample may have no weeds at the end of the season, but show low yields. Through observation you noted that there was a very late removal of weeds and this explains why there is a low yield with the apparent absence of weeds.

- Interview the person who is responsible for working in the field to find out what production and weeding practices he or she used.

- Rate the amount of weeds present in the sample at harvest.
Analysis

SURVEY ANALYSIS

Informal Survey

1. Summarizing notes

At the end of the survey, the daily notes can be summarized, and if several areas are surveyed, each area can be summarized. The final report should be a description of the various farming practices which are generally used with descriptions about any variations to that practice.

2. Tabulating data

This method helps you to organize the data. Although it was collected informally, the responses can be organized in tabular form.

- Organize the data by groups which are similar or by area.
- For each group or area:
  - If answers are all the same, do not create categories for the answers.
  - If the answers are different, create categories. Try to keep the number of categories to a minimum but make sure they make sense.
  - If the answers are in a yes/no format, simply tabulate.
  - If the question is open-ended, that is, you let the farmer give a variety of answers, then the answers become the categories. Tabulate how many gave each response.
- Check the reliability of the data. Discount any information that looks suspicious.

(See Annex for a complete example).

3. Organizing data from crop activity calendars

Refer to the Annex for an example of a crop activity calendar.

The labor calendar can be filled in for several individual farmers describing the time and occurrence of the crop production activities in the growing season for the major crops in the area. This information can then be summarized.
Identify the likely areas where there are labor bottlenecks, particularly related to weed control or land preparation activities, which partially have weed control objectives. Labor bottlenecks are where there are too many activities for the available labor to accomplish. It is often the reason why farmers are not weeding in time.

Secondly, the amount of time that a farmer spends on producing a crop as well as the amount of time spent on the various activities in crop production can be seen, summarized, and analyzed. Also see example in the Annex.

4. Making conclusions

- Rank the information according to its importance.
- Find which responses have the highest frequency and note the range in responses in any given area.
- Compare areas. Are they similar or different and how? If several areas have been surveyed, can similar areas be grouped into one category? Or should the areas remain distinct because they are too different? This helps to define or redefine recommendation domains.
- Summarize for each area and for all areas in general.

ECONOMIC ANALYSIS TECHNIQUES

Definitions

- A budget is an estimation of costs and returns.
- Variable costs are production costs that vary with the level of output. Variable costs are a function of the amount produced. Fertilizer, herbicide, and labor on a short-term basis are example of variable costs.
- Fixed costs are those costs related to production that do not change with the level of output. They remain the same whether or not output is produced. For example, equipment, machinery, plowing, and planting are fixed costs in an experiment to test the effect of different fertilizer levels. They do not vary.

Daily labor is usually a variable cost but permanent labor (hired by the year) is a fixed cost.
Net benefit = gross benefit - variable cost

Net yield = yield - (harvest and storage loss estimate)

Opportunity cost is the value of any resource, usually time, in its best alternative use. For example, if a farmer has a job that is off the farm, and this makes him give up weeding his field, then the opportunity cost of his weeding time is equal to the wage which he would have been earning if he had stayed in his job. This concept may represent the values that the subsistence farmer places on labor and grain, since there may be no actual money given up or received. The economist often assigns an estimated monetary value for these figures. Another example would be if a farmer spent one day working on his cash crop rather than weeding his maize. The time spent on the cash crop will increase its value by 10 birr. The opportunity cost for weeding the maize is 10 birr. This is the amount the farmer might have lost if he were not working on the cash crop.

Partial Budget

This is a very useful technique to determine the costs and benefits of a new technology compared to the traditional one. This calculation only deals with the variable cost changes related to the new practice, not the fixed costs.

Example: The farmer is growing two crops, teff and maize. Compare the cost effectiveness of handweeding to herbicides in the two crops.

<table>
<thead>
<tr>
<th>Information</th>
<th>Teff</th>
<th>Maize</th>
</tr>
</thead>
<tbody>
<tr>
<td>area (ha)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>yield (q/ha)</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>crop loss due to weeds</td>
<td>50%</td>
<td>30%</td>
</tr>
<tr>
<td>man days/ha weeding</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td>frequency of weeding</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>herbicide</td>
<td>2,4-D</td>
<td>Primagram 500</td>
</tr>
<tr>
<td>herbicide quantity</td>
<td>2 liters/ha</td>
<td>5 liters/ha</td>
</tr>
</tbody>
</table>
**Information**

<table>
<thead>
<tr>
<th></th>
<th>Teff</th>
<th>Maize</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herbicide cost</td>
<td>12 birr/liter</td>
<td>17 birr/liter</td>
</tr>
<tr>
<td>Selling price (birr) of crop</td>
<td>60/q</td>
<td>40/q</td>
</tr>
<tr>
<td>Labor</td>
<td>2 birr/man day</td>
<td>2 birr/man day</td>
</tr>
<tr>
<td>Labor for herbicide</td>
<td>2 birr/man day</td>
<td>2 birr/man day</td>
</tr>
</tbody>
</table>

**Maize example:**

1. **Handweeding**
   - **Variable Costs**
     
     Labor: $16 \text{ man days/ha} \times 2 \text{ ha} \times 2 \text{ birr/man days} \times 2 \text{ weedings} = 128 \text{ birr}$
   
   **Benefits**
   
   Yield = $20 \text{ q/ha} \times 2 \text{ ha} \times 40 \text{ birr/q} = 1600 \text{ birr}$
   
   **Net benefits:** $1600 \text{ birr} - 128 \text{ birr} = 1462 \text{ birr}$ for 2 ha or $736 \text{ birr}$ for 1 ha.

2. **Herbicide**
   - **Variable Costs**
     
     Herbicide costs = $5 \text{ liters/ha} \times 2 \text{ ha} \times 17 \text{ birr/liter} = 170 \text{ birr}$
     
     Labor costs = $2 \text{ ha} \times 2 \text{ man day/ha} \times 2 \text{ birr/man day} = 8 \text{ birr}$
     
     **Total** = 178 birr
   
   **Benefits**
   
   Yield = $24 \text{ q/ha} \times 40 \text{ birr/q} \times 2 \text{ ha} = 1920 \text{ birr}$
   
   (Assume higher yield with herbicide use)
   
   **Net benefits:** $1920 \text{ birr} - 178 \text{ birr} = 1742 \text{ birr}$ for 2 ha and $871 \text{ birr}$ for 1 ha.

**Conclusion:** Herbicide for weed control gives a greater return than handweeding, 736 versus 871 per ha. The net benefit ratio is $871/736 = 1.2$. 

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Teff example:

1. Handweeding

Variable costs

Labor = 15 man days/ha x 3 times = 45 man days
45 man days x 2 birr/day = 90 birr

Benefits: Yield = 10 q x 60 birr/q = 600

Net benefit = 600 birr - 90 birr = 510 birr

2. Herbicide

Variable Costs

2 liter/ha x 1 ha x 12 birr/liter = 24 birr
2 man days/ha x 2 birr/day = 4 birr for application
Total = 24 + 4 = 28 birr

Benefits

12 q x 60 birr/q = 720 birr (Assume greater yield when herbicides are used)

Net benefit = 720 birr - 28 birr = 692 birr

Conclusion: The net return for using herbicides is greater (692 birr) than that achieved by handweeding (510 birr) assuming a higher yield when herbicides are used. The ratio between the two net benefits is 692/510 = 1.4.

A ratio slightly better than one is not a sufficient difference to say that the herbicide is better. A higher ratio is needed in order to draw this conclusion with confidence.

Minimum Returns Analysis

There are three sources of yield variability in trials or demonstrations in farmer's fields which the extension worker must recognize:

- Site-to-site variability under the same management conditions.
- Year-to-year variability under the same management conditions.
- Management level variability on a given site in a given year.
Minimum returns analysis is used to examine the relative risks among alternative technologies given the variability in treatment response over time, sites, and management levels. This technique will show you the worst returns that you can get for any given treatment by taking the average across many sites. This is indicative of what a farmer might receive if he practiced the treatment under poor conditions. It gives an indication of the amount of risk inherent in any treatment which might be faced by the farmer. Trial or demonstration data is used for this analysis. Results from a minimum of 5 or 6 sites must be used. All sites from any given experiment must be included in the analysis except for those that failed because of a mistake in the implementation. If there was no yield due to an accident such as livestock eating the plot, then estimate what yield you should have received. Compare the worst net return taken from the various trial sites for each treatment. Then take the second worst result for each treatment. Take the average of these two. Compare these averages with each other. This will help to point out the most risky treatments—those having the lowest, average worst net returns. An example follows:

The following data on net benefits was collected for eight sites:

<table>
<thead>
<tr>
<th>Trial number</th>
<th>Treatment numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>360 670 410 1620</td>
</tr>
<tr>
<td>2</td>
<td>1380 1890 1200 2710</td>
</tr>
<tr>
<td>3</td>
<td>3740 3920 3700 3800</td>
</tr>
<tr>
<td>4</td>
<td>2180 2990 1820 3390</td>
</tr>
<tr>
<td>5</td>
<td>1480 1280 1540 2190</td>
</tr>
<tr>
<td>6</td>
<td>1450 2200 1330 2830</td>
</tr>
<tr>
<td>7</td>
<td>4270 4420 2120 4000</td>
</tr>
<tr>
<td>8</td>
<td>1090 1650 1080 1800</td>
</tr>
<tr>
<td>Average net benefit</td>
<td>1990 2380 2310 1900</td>
</tr>
</tbody>
</table>

Minimum net benefits from the above eight different sites:

<table>
<thead>
<tr>
<th>Treatment numbers</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worst</td>
<td>360</td>
<td>670</td>
<td>410</td>
<td>1620</td>
</tr>
<tr>
<td>Second worst</td>
<td>1090</td>
<td>1280</td>
<td>1080</td>
<td>1800</td>
</tr>
<tr>
<td>Ave. of worst two</td>
<td>725</td>
<td>975</td>
<td>745</td>
<td>1710</td>
</tr>
</tbody>
</table>

In this case, the best treatment to choose would be treatment 4 as it has the best worst returns.
Considerations for Extension of Solutions to Farmers

EXTENSION METHODS

"The less developed a country, the more competent should be the extension agent and the more areas of his competency" (Rohrer, 1986).

Attitudes Useful in Extension

In order to be effective, extension agents need to adopt certain attitudes which will help them succeed in their task. Remember that your target is the farmer.

■ It is important to realize that farmers have a 'native' intelligence and an acquired wisdom based on their experiences. This intelligence and experience is just as valid as one gained from a formal education.

■ It is important for the extension worker to understand the differences between themselves and the farmers. Extensionists need to overcome these differences by adopting and accommodating to the farmer's situation. Try to understand customs, beliefs, and language. This will help you to win the farmer's confidence.

■ It is important to realize that different people in community will have different responses to new technology or suggested change. Some farmers will be more progressive than others; they will question new methods less before they try them. They are sometimes called innovators. Others will be very resistant to change and will take more convincing. Normally, people need convincing before they will change. The extension worker must win their confidence.

■ Understand that most farmers do a good job of allocating the resources they have to meet their objectives. Their objective is usually to minimize risk but maximize returns. Usually, not much progress can be made by telling them to reorganize the use of their resources, e.g., they should weed more. Rather, focus should be on introducing new technology.

Considerations and Approaches for Introducing Technology

1. Extensionists are expected to give information and create awareness about new ideas. In order to do this they should not only have a good knowledge of the practices they are introducing but they should be familiar with existing ideas, practices and problems relating to these. They need to
understand local beliefs and attitudes in order to know how they should go about changing people through convincing them. The status of the farmer's information about a recommended technology can fall into five categories:

- They don't have the information and have no preconceived feeling about it.
- They don't have the information but have negative preconceived feelings about it.
- They have conflicting information.
- They know a lot about the subject but are resistant to the idea.
- They are well informed about the idea and are willing to try it.

2. Different farmers will have different requirements and problems; therefore, it is important to understand these differences in order to suggest technologies that will be relevant for different users.

3. The extension approach should be a joint exercise whenever possible between the extension agent and the farmer or farmer group. Encourage a 'participative' approach to identify the problem and seek solutions.

4. Understand the farmer's own system of experimentation. What new technologies has he tested in the past. Assist him in designing an experiment on his own field that will test the recommendation, using his own experimental procedures.

5. "To reduce the gap (between traditional and new methods) extension workers need to know and to respect both kinds of techniques well enough to explain the costs and benefits of both" (Rohrer, 1986).

6. One way to make new technology more acceptable, is to emphasize how the new method is similar to the old. Discuss how it can improve the quality of life. If possible, blend traditional methods with modern methods to make the change more compatible.

7. It is important to realize that replacing or modifying a traditional practice involves some changes. Analyze what this change will entail. Is it going to be compatible?

8. To communicate effectively, translate your messages into locally understood terms. Remember that farmers are more
used to an oral rather than written communication. Consider how you present yourself; choose the right time and place. Give the impression that you know about what you are talking about. Adjust your presentation to fit the type of audience that you have.

9. It is best to discuss recommendations with farmers either individually or in small groups. Give the farmer both positive and negative aspects to the proposed change but emphasize the positive aspects particularly when the technology is very new to them.

10. If possible, make several new options available to farmers, depending upon their resources and problems. Avoid a 'blanket' recommendation; that is, the same recommendation for all areas. Not all recommendations will be relevant to all farmers. Extension agents need to use judgement in deciding what to recommend to who. For example, weed pressure may be different on different farms. There may be a noxious species on one farm but not on another. Therefore, these conditions need different recommendations to deal with the problem effectively.

11. People usually adopt gradually. Follow-up is needed again and again. Even when someone adopts a practice, the extension worker should follow-up in order to see if it is being used properly. There should be feedback to research and policy makers on the adoption of technologies and problems.

12. Try to plan schedules. Use programs of work rather than day-to-day requests to organize yourself more effectively.

13. For weed management, stress prevention rather than cure.

14. Plan your presentations. Choose a main topic or theme. Present the information in a logical order. Design visual aids if necessary. Choose the main points to illustrate what you are saying. Make the message clear, simple, direct and present it in a familiar way. If you use written messages do not have too much writing because it will be confusing. Practice your presentation before giving it. Encourage audience participation. Invite them to ask questions, ask them direct questions. Pay attention to audience reactions. Remember:

"If I hear, I forget;
If I see, I remember;
If I do, I know and I understand."
(Pickett, 1978)
TECHNOLOGY ADOPTION

Factors which may be responsible for limiting adoption of technology

1. Farmers do not want to change mainly do to lack of motivation. This may be an excuse of extension or research when the real problem is another one.

2. Extension services have a weak structure or the people are untrained.

3. Availability of credit is a problem.

4. Inputs are too expensive and not available at the right time.

5. Technology is inappropriate and not accepted because it is too difficult: it uses too much labor or time and doesn't fit in with the other activities; it is too expensive; it is too risky.

6. Lack of attention to social factors governing technology choices.

7. People not involved in identifying problems and seeking solutions.

8. The product price is too low to justify the use of purchased inputs. The value of extra production does not warrant expenditure on the input.

Reasons for Adoption

1. Technology is economically and socially feasible. It will help to increase well being or decrease costs and will be secure, because risk and uncertainties associated with the practice are minimized.

2. Technology is compatible with the farmer's needs and goals. There is motivation for change.

3. The required resources are available.

4. The practice is easy to learn and to apply.

SELECTION OF APPROPRIATE WEED CONTROL MEASURES

Choosing appropriate weed control methods can be very complex. While the weed control principles remain established and unchanged, there is a limitless combination
of farming systems that can influence both the weed problems and the potential solutions. Every region has a different set of environmental conditions, as does possibly every farm, or even two adjoining fields. The endless variation in conditions leads to difficult decisions. Flexibility in arriving at solutions to weed problems must be maintained to achieve relevant recommendations. It is difficult therefore, to make a list of recommendations to fit every situation. The responsibility resides with the extension worker to make the best recommendation, appropriate for any given situation using the guidelines and principles provided.

Summary of Steps for Identifying Solutions

1. Focus on target groups separately.
2. Understand the farming systems and the implications on weed problems and their causes.

The following list of symptoms, problems and causes, is from an example of individual farmers located in a specific semi-arid area:

- **Symptom**—yield reduction
  Causes—Late planting is caused by irregular and limited rainfall. Farmers react by planting at different times in order to avoid risk. Hard-to-work soils coupled with weak and unavailable oxen for ploughing make it difficult to prepare the land before the rains. There is a lack of speedy, precise methods of land preparation and planting at the onset of the rain.

- **Symptom**—yield reduction
  Causes—Untimely weeding, especially of early planted crops, increases competition for moisture in the early growth stages. Weeding is delayed because labor is being used to plant late crops, creating a labor bottleneck. Weeding by hand is too slow. There is a lack of appropriate oxen-drawn tools for faster weeding as well as the know-how and animals trained to use the tools. Because of the lack of precision in planting, mechanical weeding is difficult to use.

- **Symptom**—Poor stand and a less competitive crop
  Causes—Inconsistent, hard soil, when coupled with low soil moisture in the absence of a planter, results in seed placement at various depths. This in turn results in uneven or sequential emergence. Poor germination caused
by low seed viability and pest damage. There is no seed dressing available. Sequential crop emergence makes the crop less competitive and if mechanical weeding is used, the farmer must wait too long for crops to be large enough.

In summary there are several factors which are reducing the crop yield: late weeding, late planting, poor seed, and pest damage to seedlings.

3. Suggestion of interventions

Every intervention or suggested technology has both positive and negative aspects. At this stage, list all possible potential solutions.

*Example:

Problem: Yield reduction in maize due to competition from weeds.

Cause: Shortage of labor for weeding.

Apparent solutions:

1. Direct solutions:
   - Plant in rows for easy recognition of weeds which look similar to crop species, as well as faster weeding.
   - Plant in rows and introduce a mechanical weeder.
   - Use a herbicide.
   - Introduce a new, more efficient planting method, such as minimum tillage.
   - Introduce dry planting with a new planter.

2. System interactive solutions:
   - Introduce fodder storage for the dry season in order to provide feed for animals, making them stronger for ploughing.
   - Introduce trees which will provide animal fodder during the dry season.

4. Outline the consequences for each solution

Ask yourself questions such as:
What changes are required to implement the new technology? Are these positive or negative effects?

How does the solution affect or interact with labor allocation to various jobs?

How does the solution interact with other farm enterprise activities, management capabilities, and attitudes?

Can the farm family afford the intervention? What are the added inputs?

Is the solution technically feasible in the situation in question?

Using some of the solutions from the example above, the following interventions are suggested:

1) More efficient and less labor-intensive planting and land preparation methods, e.g., strip or minimum tillage in order to make labor available for timely weeding.

**Expected improvements in weed management:**

Eliminate labor bottleneck at weeding time leading to earlier, more effective weeding.

More even seeding depth leading to simultaneous emergence and a more competitive crop.

Maintenance or build-up of organic matter, surface mulch which has weed control advantages, soil erosion control.

More precise row spacing making mechanical weeding more precise and earlier.

2) Herbicide use:

Faster, less laborious weed control.

**Disadvantages**

If herbicides aren't used initially, control of existing weeds may be a problem.

Increase in pests (birds) due to easier location of the seed.

Surface mulch may not be present if animals completely graze it; soil erosion hazard may increase.

New tool technology needs developing.

By controlling weeds more completely, animal feed may be sacrificed.
Maintenance or build-up of surface organic matter. Cost may not be able to be met.

Increase yield due to reduction of weed competition as compared to handweeding. Risk associated with rainfall may be too great and may make herbicide an option which is risky.

Farmers are not familiar with this technology and may not use it safely.

3) Tillage tool development: cultivators, multiple row planters, minimum tillage equipment, chisel, lightweight plough, ridgers, furrow openers, jab planters.

- Faster, more accurate complete weeding. Associated cost may be too high.
- Faster, more accurate planting and land preparation. Tools need to be developed.
- Faster, more even crop emergence and growth. Possible crop damage if row planting not precise enough.

Social acceptance of new technology.

5. Analyze which intervention now can be used to have the greatest benefits combined with the least amount of consequences.

Try to choose the best combination of weed control and production methods (land preparation, planting) using your best judgement based upon the pluses and minuses of each suggestion. Some solutions may be too costly, too risky, may not have the necessary technology developed yet, etc. These factors may eliminate them from being good possibilities for one target group, but may not be a problem for a different target group. For example, cooperatives having greater resources may be able to afford a new planter; whereas an individual farmer may not.

From the above list, it appears that herbicides would be too risky and perhaps not cost effective in this situation. Minimum tillage using the present local plough for dry seeding would be feasible in the short term, helping to eliminate the labor bottleneck which now exists between land preparation, planting, and weeding. Certain risks related to this technique, such as increased bird damage, would have to
be evaluated. Use of animal-drawn implements for weeding, even if the local plough was used, would greatly speed up the operation. Eventually, better tools could be developed to facilitate land preparation, planting, and weeding.

6. Using economic analysis to assist in deciding the optimum recommendation for target groups

In the following example, research recommended an improved maize variety, which on the station, outyielded local varieties. When the improved variety was tested further in trials under farmer's conditions, it was found to give a lower yield than the local variety. Further investigation showed that when the improved variety was grown under improved conditions, which required greater inputs or fertilizer, weeding, etc., it performed very well. Without these inputs, it performed worse than the farmer's variety. If the local variety received the inputs, it did not respond as well as the improved variety. In conclusion, the improved variety must be accompanied by the use of inputs to realize the yield increases. This recommendation is for farmers who have the resources to buy the inputs, otherwise the recommendation is to continue growing his local variety using traditional practices. Figure 11 illustrates what happened.

Net Return (Birr)

<table>
<thead>
<tr>
<th>Net Return (Birr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
</tr>
<tr>
<td>300</td>
</tr>
<tr>
<td>200</td>
</tr>
<tr>
<td>100</td>
</tr>
</tbody>
</table>

0  100  200  300  400

Total Cost (Birr)

A = improved variety with improved practices
B = traditional variety with improved practices
C = traditional variety with traditional practices
D = improved variety with traditional practices

Figure 11. Comparison of the economics of different recommendations.
'A' required an investment of 400 Birr and gave a net return (after subtracting expenses) of 300 Birr. If the local variety, in situation 'B' received the investment of 400 Birr, it only gave a net return of 80 Birr. This is less than the net return of 200 Birr which the local variety gave with the much lower investment of 150 Birr (situation 'C'). In 'D', it is obvious that the improved variety did much worse than 'C' for the same investment.

GIVING THE FARMER RECOMMENDATION ALTERNATIVES

The best possible situation is where the farmer can choose among several technologies to fit his resources. In order to do this, the extension worker needs to understand the variability and its causes in the area where he works. For weed control, variability is related to two major factors: environmental conditions and farmer management. In order to handle the variability and to know what recommendations should be given, the farm population can be divided into 'recommendation domains', as discussed earlier. Recommendations can then be suggested on this basis.

The following case is presented as an example:

Farmers in Shoa Province spend a lot of time weeding their teff. Farmers were visited and their weed problems examined. Two major levels of weed infestation were spotted in the teff fields, high and low. Then within these two categories farmers tended to have potentially higher yielding fields which were ploughed and fertilized or lower yielding fields which were poorly managed, had a low fertility, were waterlogged, or had pest problems. In the latter case, it would most likely not pay to spend additional cash for weed control because the yield potential would not be very great anyway. Thirdly, farmers either had or did not have resources. This means that if they had resources that they either had access to adequate labor or had cash to buy labor or inputs. If they did not have resources it meant that they did not have easy access to labor or cash. Therefore, eight different situations were identified and are presented in table form below:

<table>
<thead>
<tr>
<th>Weed Infestation</th>
<th>Management status</th>
<th>Resources</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. High</td>
<td>Good</td>
<td>yes</td>
<td>Herbicide + one handweeding</td>
</tr>
<tr>
<td>2. High</td>
<td>Good</td>
<td>no</td>
<td>Two handweedings</td>
</tr>
<tr>
<td>3. High</td>
<td>Poor</td>
<td>yes</td>
<td>Two handweedings</td>
</tr>
</tbody>
</table>

95
Taking these various categories as a starting point, different recommendations can be made according to individual farmer resources and conditions.

In Case No. 1, the farmer has a weed problem but has the resources to take care of it; therefore, the use of herbicides is recommended followed by a handweeding if necessary.

In Case 2, the farmer still has a weed problem but because he has fewer resources, it is recommended that he just do two handweedings rather than buy a herbicide.

In Case 3, the farmer has resources but the land does not have good potential; therefore, it is not recommended that he purchase herbicide, but instead do two handweedings.

In Case 4, the yield potential is poor and because the farmer has fewer resources only one handweeding is recommended.

In Cases 5-8, the recommendations are similar, that is to handweed one time. This is because the weed infestation is low and does not warrant any further treatment. The only exception is where the farmer may have the means to purchase a herbicide in Case 5, he then has that option.

In summary, from this exercise, there are four recommendations:

- **Herbicide + one handweeding**

For farmers who have the resources to buy the herbicide, whose land has a good production potential, and who have high weed infestation.
- **Two handweedings**
  For farmers who have high weed infestation, few resources to buy herbicides, no matter if they have good or poor production potential.

- **Herbicide only**
  For farmers who have a low weed infestation, who have a good production potential and the resources to buy a herbicide.

- **One handweeding**
  For farmers who have few weeds, good production potential but few resources or poor production potential regardless of their resources.

**REFERENCES**

The following references were used in writing Chapter II and can be found in Annex 8: 2, 4, 5, 6, 11, 12, 31, 32, 36, 39, 40, 41.
Chapter III

Weed Control in Specific Crops
General Information

These recommendations should be followed for all crops. Herbicide use is discussed in this section. All recommendations are general due to lack of sufficient data from different agroecological zones. Therefore, use them as a guide, because they may have to be modified for your area.

RULE OF THUMB

Any single weed control method or the continuous use of the same herbicides can lead to the build up of weeds resistant or tolerant to that control measure. Therefore, rotation with other crops, and/or other control measures will reduce the chance of new or unique weed infestations.

HERBICIDES

When Should Herbicides Be Used?

- Herbicides are recommended for situations where weed control by other methods is not being done on time due to labor bottlenecks, which is when there is not enough labor to complete several different activities simultaneously.
- Herbicides can give early weed control in situations where the crop is particularly sensitive to early weed competition.
- Herbicides can give good control of perennial grasses which are otherwise difficult and time consuming to control.

What Herbicides Have Been Recommended?

The herbicides that can be used in each crop are presented in tables accompanying the recommendations for each crop. Some of the herbicides recommended have been researched in Ethiopia, others have been researched or used successfully outside of Ethiopia but under similar environmental conditions. These herbicides have been included because they may be useful in Ethiopia. Preplant incorporated herbicides have not been included because of the difficulty of obtaining the machinery and skill needed for proper application.

How to Use the Herbicides Recommended

Selection of herbicide, rate and time of application should be done using the tables provided as guidelines. When
choosing, keep in mind potential crop injury problems due to inaccurate application, soil residue, or drift potential. Choose the lowest rate possible which will adequately control the weeds under your conditions.

LATE SEASON WEED CONTROL

Late season weeds may not interfere with yields, but may interfere with harvest operations. These weeds will also provide a seed source for next season's weed infestations. Trash left by weeds or those growing during the fallow periods will add to the cost of, and/or may hinder land preparation. Late season weed control is recommended.

PREVENTION

Clean implements (ploughs and hoes) to prevent spread of weed seeds or propagules from one field to another. Prevent weeds from seeding. Use clean crop seed. Prevent weeds from spreading into the field from the edges.

LAND PREPARATION METHODS

Crop and weed residues should be minimized to ensure a thorough seedbed preparation. Growing weeds should be completely eliminated before planting. A relatively smooth seedbed will make subsequent planting and cultivation operations more effective for most crops.

Minimum tillage can be practiced for some of the crops, such as maize, sorghum, large seeded pulses. Usually, herbicides are required to control weeds when this sort of system is used. Discussion on this will be included for each crop where it is applicable.

ADVANTAGES TO ROW SEEDING

If row seeding for large seeded crops such as maize and sorghum is used, the crop will be easier and faster to weed. If grass weeds which resemble sorghum or maize at early stages are present, then row seeding will help the farmer to distinguish the majority of these weeds because of their position in between the rows. When maize is row planted, interrow cultivation for weeding purposes can be done earlier and with less damage to the crop. If post-emergence herbicides are used, row planting facilitates application and fewer mistakes are made.

CROP ROTATION

Crop rotation can be an important technique for controlling
weeds in an integrated weed control program. It is useful to plant non-competitive crops after crops which have received very good weed control because this helps to decrease the weed population. Crop rotation is also important in the case of cereals to avoid buildup of harmful pests and diseases. This encourages a healthier, more competitive crop.

EARLY CULTIVATION

Most crops experience the most severe competition from weeds early in their life cycle. At this time the weeds are very small and are often difficult to remove if the major method is handpulling or hoeing. Farmers generally wait until the weeds are large enough to grasp or to hoe. Many crops are sensitive to the root disturbance caused by vigorous hoeing with large hoes. It is recommended that a small hoe or one that can dig shallowly be used for early weed control whenever possible. This will enable the farmer to weed earlier, when the weeds are small. It has been shown that weed control is much faster and more complete if it is done when the weeds are small. Even if it requires a second pass through the field, the total time is shorter compared to a single weeding when the weeds are large. In this way yield loss due to competition is avoided and root damage is lessened. Row planting helps to speed up this activity.

CRITICAL PERIOD

The critical weed-free periods presented for each crop were for the most part derived on research stations in Ethiopia or in the region. Therefore, they are not completely accurate for all situations, because results are sensitive to variations in weed flora, rainfall, etc. The data are presented to act as a guide, and indicate the sensitivity of the crop to weed competition. If more accurate data is required for your area, then you must conduct an experiment, repeated over several years and sites.

SEEDING RATE AND SPACING RECOMMENDATIONS

Generally, farmers use a seeding rate higher than the recommendation to produce a crop more competitive with weeds and to use the thinnings as animal feed. The majority of the research work to date has been with row seeded crops, whereas the majority of farmers use broadcast seeding. Therefore, recommendations may have to be modified to suite the objectives and resources of the farmer.

Row spacing recommendations have been made with precision planting methods in mind. Most farmers are reluctant to adopt such precise recommendations at this time because
precise planting is too time consuming given their resources. The recommendations are suitable for farmers who have mechanical planters or suitable time and labor. These recommendations may also need modification to suit the objectives and resources of the farmer.

FERTILIZER RECOMMENDATIONS

These recommendations have been omitted from this publication. Follow the recommendations available from other extension publications to ensure good, vigorous crop growth.

MAPS

In the Annex are two maps: one shows the thermal zones and the other shows growing seasons, based on rainfall. The thermal zones are closely related to altitude. The growing periods are divided into five types, depending upon whether the area has a double or single season as well as the length of reliable rainfall. It is reasonable to assume that seasons of different lengths with differing rainfall amounts should have both different weed species as well as different weed control requirements.

The weed control and agronomic recommendations that follow are not yet detailed enough to take into account the differences between the different types of areas where any given crop is cultivated. However, the maps should be useful for extension agents and researchers to determine what type of recommendations should be suitable for their area, e.g. long season control for high rainfall areas, good land preparation methods for areas with a short, inadequate rainfall followed by a dry period and then the main rainfall period, etc.
Weed Control in Cereals

MAIZE

Critical Weed-free Period

Maize should be kept weed free following the methods stated below, from 10 days after emergence to just before flowering, when the tips of the tassel are visible. Research results show there is a 25% reduction in yield when weeds are not removed until the fourth week after sowing; 44% yield loss if weeds are not removed for 8 weeks; and 48% if not removed for 12 weeks. Weed competition will be more serious in areas where there is a long season and high rainfall and in areas where there is a shortage of rain and intensified competition for water. If there is any drought stress, remove the weeds as soon as possible.

Land Preparation

Create a weed-free seedbed with good tilth. Depending on the soil type, two to three ploughings before the planting operation should be sufficient when the maresha is used. The last ploughing may be eliminated if a harrow can be substituted. If a tractor is used, one ploughing followed by diskimg and/or harrowing should give a good seedbed. Removal of debris such as last season's crop residues, will ensure an easier and better job. At the time of planting a third ploughing is usually done which opens the soil, covers the seed, and eliminates already emerged weeds.

If perennial grasses or sedges that reproduce by tubers are a problem, ploughing in the dry season will help to eliminate these by desiccation. Herbicides such as glyphosate can be used to kill the perennial grasses if the dry season is not long enough to facilitate desiccation.

Minimum Tillage

Minimum tillage is when soil disturbance is minimized and limited only to what is necessary to plant the seed. Herbicides must be used for weed control, especially in wetter areas when crops are planted after the rains start. A non-selective herbicide can be used first if there are growing weeds, followed by a residual herbicide to control weeds which are emerging later. (See herbicide recommendation section.) The planting is done directly into crop or dead weed residues. This technique can be used without non-selective herbicides only in dry areas where there is no weed growth before crop establishment. However, herbicides or some other method of weed control must be used.
to control later emerging weeds. If the maresha is used, planting strips can be prepared and seeded, leaving unprepared areas in between the rows. Jab planters can also be used. Research has shown advantages for using this technique in some situations, where it has potential for solving some weed problems, labor and/or draft power bottleneck problems, soil conservation problems, etc. However, this technique needs further testing in Ethiopia to better understand advantages and disadvantages.

Competitive Cropping and Good Husbandry

Choose an accurate planting method, proper spacing, and optimal population density. Plant the crop as soon after land preparation as possible. This gives the crop a competitive advantage as weeds have not had time to germinate or sprout before the crop. Plant as precisely as possible in order to ensure even depth and relatively parallel rows if using row planting. Where possible, even seeding depth will help ensure faster, uniform emergence and a more competitive crop. Parallel rows will make weeding by mechanical cultivation feasible and accurate, avoiding crop injury. The recommended planting depth is 3-5 cm when using mechanical planters. This is difficult to achieve when using traditional planting methods.

The general recommendation for row spacing is 75 cm with 30 cm within the row. Again, this precise spacing in the row is easier to obtain when using mechanical planters, but not necessarily practical for farmers using traditional methods. If using interrow cultivation, row spacing may have to be wider to avoid crop damage. Adjust to 90 cm between rows and increase the seed rate in the row to achieve the same population. The recommended seeding rate for row planted maize is 25 kg/ha. For broadcast seeded maize 30 kg/ha seed is recommended. If thinnings are needed for livestock feed, decrease the distance between seeds in the row (that is, less than 30 cm) and thin to achieve recommended spacing. If overseeded when broadcast planted, thin while weeding 2 weeks after emergence.

Number of Weedings

A general rule is to weed the crop every three weeks if weeds are present, for up to three times. In drier areas, two times may be adequate, but be sure to avoid any competition for moisture. In wetter areas, three to four times may be needed. The important thing is to keep the crop weed free during the period when competition is detrimental (10 days to tasseling).
A combination of handweeding, hoeing, shilshaloing or interrow cultivation can be used to keep the crop weed free. These methods can also supplement herbicides where weeds have escaped control. Shallow hoeing can be used with herbicides without reducing the herbicide's effectiveness. Shallow cultivation prevents exposure of untreated soil and germination of new weed seeds. If herbicides are banded over the row, shallow interrow cultivation will be required to control the weeds between the rows.

Shilshalo or Interrow Cultivation with Animal Drawn Implements

This mechanical removal of weeds can be practiced in either broadcast or row-seeded maize. In row-seeded maize the practice is usually called interrow cultivation. Shilshalo is used by farmers to weed, to thin maize, and to loosen the soil for better moisture penetration.

One or two shilshalos are required depending on labor and animal availability, the amount of rainfall, length of growing season, competition from weeds, and the size of the maize. The drier the area, the less shilshaloing will be required. If shilshalo is the only type of early weed control used, perform the first shilshalo as early as possible, as soon as the maize is large enough so that it will not be buried (20 cm) and when the weeds are not too large (not more than 15 cm). If weeds are too large (greater than 15 cm) they are more difficult to uproot completely, more soil is disturbed near the maize, and shilshalo takes longer to accomplish. Shilshalo usually has to be followed with some handweeding or hoeing to remove the weeds which are left. The first weeding should take place around 2 weeks after emergence. A subsequent shilshalo should be done when the maize is knee high.

Shilshalo when there is adequate, but not too much soil moisture or when rain is expected soon after completion to assist the crop in recovering from the disturbance. Do not shilshalo or use interrow cultivation when the maize is too large (greater than 50 cm) because crop damage will be too great.

Shilshalo may be preceded, especially in higher rainfall areas or where there is a shortage of draft power, by hoeing or handweeding because the weeds will be too large if weeding is delayed.

Hoeing and Handpulling

These two methods can be used instead of, or to supplement
interrow cultivation or shilshalo; however, they are more tedious and time consuming to perform. When the maize is too large for shilshalo, hoeing or handpulling must be used to maintain the crop weed free during the critical period. When hoeing, avoid deep cultivation near the roots of the maize because this will decrease the yield. Remove the weeds when they are less than 15 cm tall because this will make removal faster and more complete as well as prevent competition with the crop.

Cultivation Using Tractor Drawn Implements

Shovel or sweep cultivators or rotary hoes are the most useful, efficient tractor drawn weeder. A high speed (10 kph) shallow (2.5-3.5 cm) cultivation with a rotary hoe when maize is 7-8 cm tall will help control small weed seedlings. This technique will not reduce herbicide action and may in some years enhance chemical weed control by helping to mix the herbicides with the soil. The cultivators and tractor speed should be adjusted so that the minimum amount of soil is moved but so the weeding job is as complete as possible. In-row weeds can be buried by thrown soil thus eliminating, in many cases, intensive handweeding in the row. Cultivations can be done until the maize is 50 cm tall. If cultivation is too deep (15 cm near the base of the maize plant) roots will be damaged.

Cultivation will help to control perennial weeds but may also help to spread them to uninfested fields. If cultivating fields infested with perennial weeds, clean machinery when moving between fields and try to cultivate the infested fields last.

Mulching

In higher rainfall areas, it may be feasible to use the residues from the pulled weeds which have not produced seed to mulch the maize within the rows. This will help prevent excessive weed growth near the crop plants. Avoid where termites pose a problem.

Cutting and Mowing

This technique is useful when it is too wet to cultivate or handweed effectively and/or when it is later in the season and weeds need to be controlled to prevent seeding. However, cutting and mowing should not replace other methods, when it is possible to use them, because they are much more effective. When slashed, some weeds, such as perennial grasses, sedges, other low growing weeds, will regrow rapidly and can cause further competition.
Guide to herbicides for use in maize

Note: For intercropped maize, select a herbicide or mixture of herbicides that is safe for both crops.

<table>
<thead>
<tr>
<th>HERBICIDE, TRADE NAME &amp; FORMULATION</th>
<th>DOSE PRODUCT LITERS/HA</th>
<th>CROP STAGE</th>
<th>WEED STAGE</th>
<th>WEEDS CONTROLLED</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>*# alachlor Lasso (480 g/Liter EC)</td>
<td>5.0</td>
<td>Pre-emergence</td>
<td>Pre emergence or very early post emergence before weeds are 2-leaf stage of grasses</td>
<td>Many annual grasses and some broadleafed weeds. Rottboellia is resistant.</td>
<td>Use low dose on light soils. Apply to weed-free soil of fine tilth. Moist soil at application or rain within 10 days is required. Tends to be short-lived.</td>
</tr>
<tr>
<td>*# alachlor + atrazine Lasso/atrazine (350 + 200 g/Liter FW)</td>
<td>6.0</td>
<td>Pre-emergence</td>
<td>Pre-emergence or early post emergence before weeds are 3 cm tall; grassy weeds should be maximum 2 leaf stage</td>
<td>Many annual grasses and broadleafed weeds but not Rottboellia.</td>
<td>Use low dose where soil contains less than 40% clay. Apply to soil of fine tilth. Moist soil at application or rain within 10 days. Use to control build-up of grasses.</td>
</tr>
</tbody>
</table>
Guide to herbicides used in maize, continued

<table>
<thead>
<tr>
<th>HERBICIDE, TRADE NAME &amp; FORMULATION</th>
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</tr>
</thead>
<tbody>
<tr>
<td># atrazine</td>
<td>4.0</td>
<td>Pre-emergence or post emergence</td>
<td>Pre-emergence or early post emergence when annual grasses are 1-3 leaf stage; broadleaves 5-10 cm</td>
<td>Many annual broad-leafed weeds and some grasses, but not Rottboellia.</td>
<td>Apply to well-prepared, moist soil when rain can be expected within a few days. In dry conditions, incorporate. Use low dose on sandy soil.</td>
</tr>
<tr>
<td>Gesaprim</td>
<td>(500 g/liter FW)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># atrazine + metolachlor Primagram</td>
<td>4.0</td>
<td>Pre-emergence and up to 3-leaf stage.</td>
<td>Pre-emergence or early post emergence before weeds are 3 cm tall</td>
<td>Many annual grasses and broadleafed weeds. Rottboellia is resistant. Moderate control of C. esculentus.</td>
<td>Use low dose on light soils. Apply to well-prepared moist soil. In dry conditions, incorporate.</td>
</tr>
<tr>
<td>(250 + 250 g/liter FW)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>* Primextra</td>
<td>(200 + 300 g/liter FW)</td>
<td></td>
<td></td>
<td></td>
<td>Less residue problems, greater grass control.</td>
</tr>
</tbody>
</table>
## Guide to herbicides used in maize, continued

<table>
<thead>
<tr>
<th>HERBICIDE, TRADE NAME &amp; FORMULATION</th>
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<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td># bentazon</td>
<td>2.0-4.0</td>
<td>Post emergence Post emergence</td>
<td>Many annual broad-leaved weeds and moderate control of Cyperus esculentus, Nutsedge should be 15-20 cm at time of spraying</td>
<td>Even coverage of leaf surface is required. No rain should fall within several hours of application. A 2nd application 10 days later may be necessary to control nutsedge.</td>
<td></td>
</tr>
<tr>
<td>Basagran (480 g/liter EC)</td>
<td>4.0-5.0</td>
<td>Post emergence from 2-3 leaf stage onwards</td>
<td>Nutsedge should be 15-20 cm at time of spraying</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(nutsedge)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*# cyanazine + atrazine 6.0</td>
<td>Pre-emergence or post emergence</td>
<td>Many broadleaved weeds and some annual grasses but not Rottboellia.</td>
<td></td>
<td>Apply to well prepared weed-free, moist soil when rain can be expected within 24 hrs. Less problem with residues than atrazine alone. Do not use on soils high in organic matter.</td>
<td></td>
</tr>
<tr>
<td>Blazine (250 + 250 g/liter FW)</td>
<td>Pre-emergence up to 4-6 leaf stage</td>
<td>Many annual broad-leaved weeds and 2 leaf stage, broadleaves 5-10 cm</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Guide to herbicides used in maize, continued

<table>
<thead>
<tr>
<th>HERBICIDE TRADE NAME &amp; FORMULATION</th>
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</tr>
</thead>
<tbody>
<tr>
<td># metolachlor Dual (720 g/liter EC)</td>
<td>1.5-3.0 Pre-emergence, up to 4 weeks before planting</td>
<td>Pre-emergence</td>
<td>Many annual grasses but not Rottboellia.</td>
<td>Has drought resistance and can withstand hot, dry conditions for 10-14 days. C. esculentus can be controlled in certain conditions. Poor control of broadleaved weeds.</td>
<td>Best results when applied to moist soil or when rain is expected. Mix with atrazine to improve control of broadleaves. Control is reduced under long dry spells.</td>
</tr>
<tr>
<td># pendimethalin Stomp (500 g/liter EC)</td>
<td>3.0-4.0 Pre-emergence immediately after planting</td>
<td>Pre-emergence</td>
<td>Many annual grasses and some broadleaved weeds. Rottboellia is usually controlled.</td>
<td>Use low dose on light or low organic matter soils. Mix with atrazine to improve control of broadleaves. Avoid drift.</td>
<td></td>
</tr>
<tr>
<td>*# 2,4-D many brands (720 g/liter EC common)</td>
<td>1.0 Post emergence when 20-30 cm tall, avoiding contact with upper leaves</td>
<td>Post emergence to actively growing young weeds</td>
<td>Many annual broad-leaved weeds.</td>
<td>Maize cultivars vary in their tolerance. Avoid drift.</td>
<td></td>
</tr>
</tbody>
</table>

* Recommended by Institute for Agricultural Research  # Recommended in other countries in the region
Noxious Weeds

The parasitic weeds, Striga hermonthica and Striga asiatica are very serious. Perennial grasses and Rottboellia conchinchinensis are two other noxious weeds in maize. (See Chapter IV for control measures).

Herbicides

Refer to the table.

Note: Some cultivars may be sensitive to 2,4-D and linuron.

Herbicides have been shown to be very economic and effective when compared to handweeding and hoeing.

Atrazine may leave a residue that will affect subsequent cereal crops (wheat, barley, teff).

Rates may be able to be reduced only when supplementary handweeding or hoeing is used.

SORGHUM

Critical Weed-free Period

The critical period of weed competition depends on the temperature and rainfall in the area. In drier areas it is important to keep the crop weed free early, between 10-30 days after emergence, or when plants reach 15 cm in height. In wetter, cooler areas the crop should be kept weed free from 10-15 days after emergence to just before flowering.

Yield reductions reported for Ethiopia for the wetter, cooler areas are 30% if weeding is delayed and 42% loss if there is no weeding at all. Generally, sorghum is less affected by weeds than maize but maintenance of the crop is still important.

Land Preparation

In drier areas, good results are obtained by ploughing easy-to-work soils during the dry season before the rains begin. This allows for early and fast planting in order to take advantage of possibly limited or erratic rainfall. This practice also exposes weed seeds and rhizomes to desiccation. If possible, weeds should not be allowed to grow on the land during the preceding dry season because this depletes moisture needed for crop growth. In all conditions, remove the crop residues for disease and insect pest control and so that good seedbed preparation can be made.
Competitive Cropping and Good Husbandry

Use a variety that is well-adapted and planted at the right time with a population and spacing suitable for the area. Check recommended planting times for each area from extension. General recommendations are to not plant after there has been heavy rain in higher rainfall areas but to plant on residual moisture. Plant immediately after land preparation has been completed. In some cases, the final land preparation will include the planting operation.

If broadcast seeded use 10-12 kg/ha. If the crop is too dense, thin it out. If row seeded, use 5-7 kg/ha with 75 cm between rows and 20-30 cm between plants. Try to sow the crop at an even depth of 2-3 cm. In some areas farmers need the thinnings for animal feed. In this case, increase the seed rate. In dry areas the seed rate should be slightly lower and in wet areas use these recommendations as a guideline. Row planting can have the same advantages as for maize.

Number of Weedings

One to two weedings in dry areas is recommended. The first at 2-3 weeks after crop emergence and if necessary a second weeding 7-8 weeks after emergence. Three to four weedings in wetter areas are recommended. The number of weedings depends upon the rainfall, variety competitiveness, and weeds present. The important thing is to maintain the crop weed free during the critical period of competition. A suggested timing for wetter areas is 2, 4, and 6 weeks after planting. Weeding can also help to control diseases and insect pests which live on the weeds as alternative hosts.

Shilshalo or Interrow Cultivation with Animal Drawn Implements

This mechanical removal of weeds can be practiced in either broadcast or row-seeded sorghum in a similar fashion to maize grown in wetter areas. For drier areas, reduce the amount of shilshalo to one, done when the sorghum is 30-50 cm followed by hoeing and handpulling to remove any remaining weeds. Proceed with hoeing if the weed growth is greater than 15 cm before the sorghum has reached a suitable size for shilshalo.

Hoeing and Handpulling

Follow the recommendation given for maize. Adjust the timing and number if the area is dry to the weeding frequency and timing recommendation given above.
## Guide to herbicides used in sorghum

<table>
<thead>
<tr>
<th>HERBICIDE, TRADE NAME &amp; FORMULATION</th>
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</tr>
</thead>
<tbody>
<tr>
<td># atrazine</td>
<td>4.0</td>
<td>Post emergence</td>
<td>Pre-emergence</td>
<td>Annual broadleafed weeds and some germinating grasses</td>
<td>Use low dose on sandy soils. Deep sowing is advised. Some varieties may be damaged.</td>
</tr>
<tr>
<td>Gesaprim</td>
<td>(500 g/liter FW)</td>
<td>at 3-4 leaf stage</td>
<td>and early post emergence before weeds are 4 cm tall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>* atrazine + metolachlor</td>
<td>4.0</td>
<td>Pre-emergence</td>
<td>Pre-emergence or early post emergence before weeds are 3 cm tall</td>
<td>Many annual grasses and broadleafed weeds. Some control of Cyperus esculentus. Rottboellia not controlled.</td>
<td>Use low dose on sandy soils incorporate if dry. Moisture needed.</td>
</tr>
<tr>
<td>Primagram</td>
<td>(250 + 250 g/liter FW)</td>
<td>and up to 3 leaf stage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># atrazine + terbutryne</td>
<td>4.0-5.0</td>
<td>Pre-emergence</td>
<td>Pre-emergence</td>
<td>Many annual grasses and broadleafed weeds.</td>
<td>Apply to moist soil. Do not apply after sorghum has emerged.</td>
</tr>
<tr>
<td>Gesaprim Combi</td>
<td>(250 + 250 g/liter FW)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># bentazon</td>
<td>1.6-2.0</td>
<td>Early post emergence</td>
<td>Early post emergence</td>
<td>Many broadleafed weeds. Some control of Cyperus esculentus.</td>
<td>Spray at least 8 hours before rain is expected.</td>
</tr>
<tr>
<td>Basagran</td>
<td>(480 g/liter EC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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## Guide to herbicides used in sorghum

<table>
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</tr>
</thead>
<tbody>
<tr>
<td># 2,4-D</td>
<td>0.5-0.8</td>
<td>Post emergence when crop is 10-30 cm tall</td>
<td>Post emergence to actively growing weeds</td>
<td>Many annual broad-leaved weeds.</td>
<td>Avoid drift. Some varieties may be injured.</td>
</tr>
</tbody>
</table>

* Recommended by Institute for Agricultural Research

# Recommended for use in other countries in the region.
Cultivation Using Tractor Drawn Implements

Follow the recommendations given for maize.

Mulching

Follow the recommendations given for maize. In drier areas, this is usually not be feasible because of the lack of mulch materials. Avoid where termites are a problem.

Cutting and Mowing

Follow the recommendations given for maize. Do not use this technique in dry areas because competition for moisture will be too severe.

Noxious Weeds

The parasitic weeds Striga hermonthica and Striga asiatica are very serious. Wild sorghum is also a serious problem because it cannot be distinguished from the crop until flowering. Refer to Chapter IV for the control of parasitic weeds.

Herbicides -- Refer to the table.

Sorghum is generally more sensitive to herbicides than maize; therefore, greater caution must be taken and use recommendations followed precisely in order to avoid any crop injury.

WHEAT AND BARLEY

Critical Weed-free Period

Wheat and barley are most sensitive to weed competition and suffer greatest yield reduction up to their 3-6 leaf stage. This is approximately between 2 and 4 weeks after emergence. Weeds emerging after this time have less competitive effect but may interfere with harvest and act as a subsequent infestation source. Grass and sedge weeds are more difficult to control than broadleafed species due to the selective nature of available herbicides and difficulties of distinguishing species during handweeding. Average yield losses in wheat and barley when the crop has received no weed control are about 37% and 18% respectively. Wheat is more sensitive than barley to weed competition.

Wild oats can be very damaging. Forty-five percent yield losses in wheat and 30% in barley have been reported for moderate infestations.
Land Preparation

Conventional tillage

When using conventional tillage methods, both barley and wheat require a smooth seedbed which is free of weed and crop residues. Recommendations are to avoid sowing where a cereal crop was grown the previous year; however, in many areas in Ethiopia, up to 90% of the land is cropped to cereals, thus this recommendation may be difficult to practice. If possible, plant on land previously planted to a legume or oilseed crop. Planting on previously fallow land is also suitable, but in practice more difficult to do. Both crops do best if the land is ploughed two to three times before sowing and once for seed covering. For wheat and barley planted on previously cropped land in areas with two distinct rainfall periods, it is recommended to plough once or twice during the short rains and the third time after the main rains begin, followed directly by planting to ensure a minimal weed population during early crop growth.

For barley planted into fallow land, it is recommended that there should be two ploughings at the end of the main rainy season and one to two ploughings just before or at the beginning of the next main rains, followed by one ploughing for seed covering.

If a tractor is used, plough once after the short rain, then disk. After more rain, disk again just before planting. If broadcasting seed, cover the seed using the tractor harrow.

If a fallow precedes wheat or barley establishment for moisture conservation reasons, it is important that the fallow land be weed free because weeds will deplete the moisture. Use ploughing if the weeds are numerous and other more labor intensive methods such as hoeing, handweeding, or slashing if the weeds are not numerous. Grazing can also help control the weeds, until planting time.

Minimum tillage

There is potential for using minimum tillage or direct drilling, especially for large scale producers who have access to machinery and herbicides; however, there should first be more research in Ethiopia. With minimum tillage, it is very important to use herbicides to maintain weed-free conditions at planting and during crop growth.

Stale Seedbed

Land is prepared using conventional ploughing during the
short rains. Weeds are allowed to germinate between the two ploughings, then are destroyed by the second ploughing. When the main rains begin, there is no further ploughing, but weeds which have germinated are controlled by a spray of non-selective herbicide, such as paraquat or glyphosate, just before planting. Planting is done directly into this treated soil with as little disturbance as possible. This technique requires more sophisticated inputs than normally available to small farmers.

Competitive Cropping and Good Husbandry

Use clean seed and choose a population and spacing conducive to high yields. Both crops can be broadcast or row seeded with a mechanical planter. If row planted, sow rows 15-20 cm apart. Row seeding rate should be as follows: bread wheat, 100 kg/ha; durum wheat, 125 kg/ha; food barley, 85-100 kg/ha; malting barley, 75 kg/ha. If broadcasting seed use the following rates: bread wheat, 175 kg/ha; durum wheat, 150 kg/ha; food barley, 125-150 kg/ha; malting barley, 100 kg/ha. Plant crops in time to avoid frost damage at the end of the season. Plant seeds 3-5 cm deep to insure even emergence and good germination.

Number of Handweedings

Two handweedings has shown to be the most economic practice and produce the best results in most areas. In drier areas, only one handweeding may be needed. The first handweeding should be done 2-3 weeks after emergence (at early tillering stage) and the second 4-5 weeks after emergence (at stem elongation stage). The second weeding would be delayed to 5 weeks if the first weeding was at 3 weeks. A third handweeding may be necessary if there are large numbers of weeds. Do not handweed after the crop has started to boot as this will cause too much damage. The timing may have to be adjusted because the growth stages will vary with the environment; that is, later in cooler, drier places and earlier in warmer, wetter places. If wild oats are present, remove as soon as the weeds are distinguishable. In this case, do not be as concerned about crop damage as it is more important to minimize wild oat infestations for future years.

Handweeding can be combined with herbicide use to remove noxious weeds or those escaping herbicide control.

Be careful to minimize crop damage when handweeding. It is best to pull up weeds before they are very large. Pull when 15 cm or less. Pulling large weeds disturbs too much soil as well as causing yield loss due to competition.
Guide to herbicides used in wheat and barley

<table>
<thead>
<tr>
<th>HERBICIDE, TRADE NAME &amp; FORMULATION</th>
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</thead>
<tbody>
<tr>
<td>*# barban Carbine (125 g/liter EC)</td>
<td>8.0</td>
<td>Post emergence but do not apply after 4 leaf stage</td>
<td>Post emergence when majority of wild oats are in 2 leaf stage</td>
<td>Only controls wild oats.</td>
<td>Be sure majority of wild oats in 2 leaf stage because this is only susceptible time.</td>
</tr>
<tr>
<td>*# bentazon Basagran (480 g/liter EC)</td>
<td>2.0-3.5</td>
<td>Post emergence at any growth stage</td>
<td>Post emergence at 3 - 4 leaf stage</td>
<td>Many annual broad-leaved weeds. Some control of C. esculentus.</td>
<td>Do not apply if rain expected within 8 hours.</td>
</tr>
<tr>
<td>*# bromoxynil + MCPA Buctril M (400 g/liter EC)</td>
<td>1.4</td>
<td>Post emergence at 2-3 leaf stage to tiller formation</td>
<td>Post emergence to young weeds</td>
<td>Many annual broad-leaved weeds.</td>
<td>Do not apply if crop under drought stress.</td>
</tr>
<tr>
<td>Brominal Plus (525 g/liter EC)</td>
<td>1.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*# bromoxynil + ioxynil + mecoprop (CMPP) Brittlex (525 g/liter EC)</td>
<td>2.0-2.5</td>
<td>Post emergence from 3 leaf up to and including jointing (6 leaf stage)</td>
<td>Post emergence to young weeds</td>
<td>Many annual broad-leaved weeds.</td>
<td></td>
</tr>
</tbody>
</table>
# Guide to herbicides used in wheat and barley

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</thead>
<tbody>
<tr>
<td>*# chlortoluron Dicuran (500 g/liter FW) (800 g/kg WP)</td>
<td>3.0-5.0</td>
<td>1.8-3.1 kg</td>
<td>Pre-emergence</td>
<td>Pre-emergence</td>
<td>Annual grasses and broadleafed weeds. Apply to moist soil. Do not use on sandy soils. Some varieties may be injured.</td>
</tr>
<tr>
<td>*# diclorprop (2,4-DP) U-46 DP-Fluid (620 g/liter EC)</td>
<td>2.5-4.0</td>
<td></td>
<td>Post emergence at 5 leaf stage to start of tillering</td>
<td>Post emergence to young weeds</td>
<td>Many broadleafed weeds. Avoid drift.</td>
</tr>
<tr>
<td>*# diclofop-methyl Iloxa (360 g/liter EC) (280 g/liter EC)</td>
<td>2.5</td>
<td>3.0</td>
<td>Post emergence Wheat- from emergence. Barley- from emergence to 4 fully expanded leaves</td>
<td>Post emergence at 1-4 leaf stage</td>
<td>Annual grasses including wild oats, actively growing. Grasses should be Lolium, Rotboellia.</td>
</tr>
</tbody>
</table>
## Guide to herbicides used in wheat and barley

<table>
<thead>
<tr>
<th>HERBICIDE, TRADE NAME &amp; FORMULATION</th>
<th>DOSE PRODUCT LITERS/HA</th>
<th>CROP STAGE</th>
<th>WEED STAGE</th>
<th>WEEDS CONTROLLED</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>#</em> difenzoquat Average (250 g/liter EC)</td>
<td>3.2-4.8</td>
<td>Post emergence from tillering to first node</td>
<td>Post emergence when 3-5 leaf stage</td>
<td>Wild oats.</td>
<td>Can be used with 2,4-D and other broadleaf killers. Avoid drift. Do not apply if rain expected within 8 hrs. Do not apply when the crop is wet. Wheat varieties differ in tolerance.</td>
</tr>
<tr>
<td><em>#</em> flumioxazin (180 g/liter EC)</td>
<td>3.0</td>
<td>Post emergence from end tillering to 2nd node.</td>
<td>Post emergence to actively growing wild oats</td>
<td>Wild oats.</td>
<td>Do not apply within 7 days of applying hormone weed killers.</td>
</tr>
<tr>
<td><em>#</em> MCPA U-66 H-Fluid (525 g/liter EC)</td>
<td>1.9</td>
<td>Post emergence when fully tillered but not in boot or dough stage</td>
<td>Post emergence to actively growing weeds</td>
<td>Many broadleafed weeds.</td>
<td>Avoid drift.</td>
</tr>
<tr>
<td><em>#</em> MCPA U-66 H-Fluid (415 g/liter EC)</td>
<td>2.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Guide to herbicides used in wheat and barley

<table>
<thead>
<tr>
<th>HERBICIDE, TRADE NAME &amp; FORMULATION</th>
<th>DOSE PRODUCT LITERS/HA</th>
<th>CROP STAGE</th>
<th>WEED STAGE</th>
<th>WEEDS CONTROLLED</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>*# mecoprop (MCPP) U-46 KV Fluid (600 g/liter EC)</td>
<td>3.2</td>
<td>Post emergence at 4-6 leaf stage</td>
<td>Post emergence to actively growing weeds</td>
<td>Many broadleafed weeds.</td>
<td>Avoid drift. Do not apply in unusually hot or wet weather. Slow in action.</td>
</tr>
<tr>
<td>*# pendimethalin Stomp (500 g/liter EC)</td>
<td>3.0</td>
<td>Pre-emergence</td>
<td>Pre-emergence</td>
<td>Annual grasses and broadleafed weeds.</td>
<td>Sow crop at least 3 cm deep.</td>
</tr>
<tr>
<td>*# terbutryne Igran (500 g/liter FU)</td>
<td>1.6-2.0</td>
<td>Pre-emergence</td>
<td>Pre-emergence</td>
<td>Broadleafed weeds and annual grasses including Setaria.</td>
<td>Apply to moist soil. Do not use on soils with low organic matter.</td>
</tr>
<tr>
<td>*# 2,4-D amine U-46 D Fluid (720 g/liter EC)</td>
<td>1.0-2.0</td>
<td>Post emergence at 5 leaf stage (no tillers)</td>
<td>Post emergence to young, vigorously growing weeds</td>
<td>Many annual and perennial broadleafed weeds.</td>
<td>Avoid drift.</td>
</tr>
</tbody>
</table>

* Recommended by Institute of Agricultural Research
# Recommended for use by other countries in the region.
Cultivation

Cultivation is very difficult to accomplish in this closely spaced crop.

Herbicides

Refer to the table for recommendations.

Wheat and barley can be damaged if herbicide application methods, rates, and timings are inaccurate. Herbicide dose, weather conditions, and crop growth stage must be noted.

Crop growth stage should be determined by counting all the leaves (where the leaf tip of the succeeding leaf can be seen) on the main stem, no matter how withered they may be. Take an average growth stage from sample plants collected in various parts of the field. This technique should be used when using the following post-emergence herbicides in order to avoid injury: MCPA, 2,4-D amine, diclofop-methyl.

Prevention

Sow clean, weed-free seed. Do not harvest the crop with the weeds. If there is a weedy area, separate out the weeds; later cut, remove and burn the weeds that are left. Use a clean threshing area. Following this advice should help to eliminate or keep out problem weeds.

Noxious Weeds

Wild oats (Avena sp.) can be very problematic because this species can cause severe crop losses. Generally, grass weeds such as Lolium sp., Bromus sp., Setaria sp., Snowdenia polystachya, are more difficult to control because of the difficulty of handweeding them at early stages when they resemble the crop. If selective herbicides are not available and handweeding is the only option, row planting the crop can help to facilitate grass weed removal. Use this only where the infestation level is high.

TEFF

Critical Weed-free Period

TEFF is initially very sensitive to weed competition because it is a very small seeded crop. Keep the crop free of weeds between 15 cm (at early tillering) and pre-heading stage. This period is approximately 3-7 weeks after emergence. Yield losses due to poor or no handweeding have been reported to be between 23-65%.
Land Preparation

Land should be well-prepared with a smooth seedbed free from growing weeds. This is very important, because good land preparation can control early weeds when the crop is very small and sensitive to weed competition and before handweeding or post-emergence herbicides can be used. Problematic weeds, such as perennial grasses or *Argemone mexicana* that are difficult to handweed or remove later, should be thoroughly removed prior to planting teff during land preparation. A minimum of four ploughings with the local maresha plough is usually necessary to achieve a good seedbed. It is recommended that the first ploughing begin in the short rains, then plough repeatedly until the seedbed is achieved. The last ploughing should be just before planting.

The stale seedbed technique, where some of the ploughing is replaced by using a non-selective herbicide such as paraquat, has been tested and in some years has proved to be very effective in reducing the weed population. The results have been variable and the technique needs further testing.

Competitive Cropping and Good Husbandry

The best time to plant in most areas is between mid-July to mid-August depending upon the rainfall patterns. Broadcast seed and then pack the soil using animals or a roller if using a tractor. On black soils the recommended seed rate is 30 kg/ha and on other soils use 25 kg/ha.

Number of Weedings

The number of required weedings depends upon the severity of the weed infestation and crop vigor. In many cases, one handweeding when the crop is 15 cm tall (approximately 3-4 weeks after emergence) has been shown to be most economic when the weed infestation is moderate. However, if the weed infestation is high, two handweedings are necessary: one at early tillering stage (15 cm) and the second at pre-heading (approximately 1 month after the first one). Do not weed teff after heading stage because it is very sensitive to damage from the disturbance.

Cultivation or Hoeing

Because the crop is broadcast seeded and very sensitive to disturbance. This is too difficult to do and is discouraged.

Roguing

Roguing is a type of handpulling when the weeds are large.
Guide to herbicides used in teff

<table>
<thead>
<tr>
<th>HERBICIDE, TRADE NAME &amp; FORMULATION</th>
<th>DOSE PRODUCT</th>
<th>CROP STAGE</th>
<th>WEED STAGE</th>
<th>WEEDS CONTROLLED</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>dichloropyridil U-46 DP Fluid (620 g/liter EC)</td>
<td>3.2</td>
<td>Post emergence at 5-15 cm or 4-5 weeks after planting</td>
<td>Post emergence</td>
<td>Annual broadleafed weeds.</td>
<td>Avoid drift. Some regrowth may occur on some species.</td>
</tr>
<tr>
<td>MCPA U-46 M-Fluid (415 g/liter EC)</td>
<td>2.4</td>
<td>Post emergence at 5-15 cm tall or at 4-5 weeks after planting</td>
<td>Post emergence</td>
<td>Annual broadleafed weeds. Bindweed.</td>
<td>Avoid drift.</td>
</tr>
<tr>
<td>(625 g/liter EC)</td>
<td>1.6</td>
<td>Post emergence at actively growing weeds</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2,4-D U-46 M-Fluid (720 g/liter EC)</td>
<td>1.0</td>
<td>Post emergence at 5-15 cm tall or at 4-5 weeks after planting</td>
<td>Post emergence</td>
<td>Many annual broadleafed weeds.</td>
<td>Avoid drift. Heavy rains will remove herbicide. Delay any cultivation as long as possible.</td>
</tr>
</tbody>
</table>

* Recommended by Institute for Agricultural Research
It should be done to eliminate problematic, potentially noxious weeds, particularly grasses, which were missed in the first one or two handweedings. It is important to try to remove as many of these as possible because they are difficult to control in other ways.

Rotation

It is important that teff be preceded by a crop which had good weed control. This will help to reduce the number of weeds which are infesting the teff. Such crops include: chickpea, wheat, barley, noug, or teff.

Herbicides

The majority of the herbicides which are selective and do not injure the crop only control broadleafed weeds. If weed infestation is severe, then herbicide use may have to be combined with handweeding to control weeds which were not killed by the herbicide.

Prevention

It is very important to use clean seed, without any weed seeds. Because teff is sensitive to weed competition and handweeding is very laborious, it is important to reduce the number of weeds. When harvesting, avoid weeds. Remove any weeds left after harvest to prevent seeding. It is important to thresh teff in a weed-free, clean area.

FINGER MILLET

Critical Weed-free Period

Little information is available concerning the necessary weed-free period for finger millet. Generally, during the first month of growth, finger millet is most sensitive to weed competition. Yield loss figures are not available.

Land Preparation

Two ploughings are recommended, one early and the second just before planting. When the crop is grown in drier areas, prevent weeds from growing during the dry season because this will remove moisture from the soil which is needed for the crop. Remove a heavy weed infestation by ploughing, or use handpulling, hoeing, or slashing if there are few weeds. The land should be relatively smooth and free of crop or weed residues at planting.
Competitive Cropping and Good Husbandry

Finger millet can be broadcast seeded, which is traditional, or row planted. If row planted, plant in narrow rows 20 cm apart using 30 kg/ha seed rate. If broadcast seeded, use 35-40 kg/ha. Plant on well-drained soils because finger millet is sensitive to waterlogging. Avoid sandy soils. Thinning, if needed, can be done at the time of the first weeding.

Number of Weedings

Because finger millet is initially slow growing, 2-3 weedings will be necessary, depending upon the weed pressure.

Handweeding and Hoeing

Perform the first handweeding as soon as possible, when the crop is 3-7 cm tall. Be careful when weeding because the crop is very sensitive to damage. Row planting can help to distinguish grass weeds from the crop. The second weeding should be 10-14 days later, and the third, if needed, 2 weeks later. Although the crop is sensitive to disturbance, the use of a small hoe, knife, or pointed stick can help in handweeding especially if seeded in rows.

Interrow Cultivation

Because the crop has closely spaced rows or is broadcast seeded, it is difficult to use mechanical cultivation. Hoes can be used carefully.

Intercropping

Although there has been no research in Ethiopia on intercropping finger millet, it has been successful in other countries in Africa, particularly with groundnuts or cowpea. These more competitive crops can help to compete with weeds.

Prevention

Use clean, weed-free seed. When harvesting, separate the weeds from the crop, similar to teff recommendations.

Herbicides

Herbicides are not recommended for this crop.

Noxious Weeds

The parasitic weed, *Striga* spp., can attack this crop.
Follow control recommendations in later chapter. Grass weeds can be a particular problem in this crop because it is difficult to distinguish them from the crop, especially *Eleusine indica* or *E. africana*. If these are a problem, grow the crop in rows. Precede the finger millet crop with a legume or oilseed crop where grass weeds can be more easily eliminated ahead of time.
Weed Control in Oilseed Crops

NOUG (NIGER SEED)

Critical Weed-free Period

There is no information on the critical period or yield reduction due to weeds.

Land Preparation

Although traditionally land is ploughed once, it is recommended to do two ploughings, plus seed covering in order to have a better seedbed. Do not prepare the soil too well because this will cause the noug to lodge.

Competitive Cropping and Good Husbandry

Noug grows well in waterlogged conditions and in soils of low fertility. If the soil is too fertile, the noug will lodge. The crop does not need too much moisture; therefore, planting can take place later in the season. Generally, the crop is broadcast seeded at 20-30 kg/ha. Where it is row seeded with 25-30 cm between rows, use 10-15 kg/ha.

Number of Weedings

Normally, farmers do not weed this crop because it competes very well with weeds. If land is prepared well resulting in a clean seedbed, if there are no perennial weed problems, and if there is good crop establishment, then no handweeding will be needed. If however these conditions are not met, then one handweeding may be needed approximately 3 weeks after planting.

Handpulling

This is the recommended method of weed control, if it is needed. Use this method to rogue out any problem weeds including 'mescal flower' (Guizotia scabra) which resembles the crop. This will help to eliminate it as a future weed problem.

Herbicides

Herbicides are not recommended for this crop.

Noxious Weeds

Grobanche spp. and Cuscuta spp., two parasitic weeds, can offer problems in some areas of the country. Cuscuta seed as
a contaminant can prevent export and therefore sale of this crop. Perennial grasses may be a problem. Follow recommendations in Chapter IV.

Prevention

Use clean, weed-free seed.

LINSEED

Critical Weed-free Period

There is no information on critical period or yield reductions due to weeds.

Land Preparation

Land should be well-prepared by ploughing 2-3 times, with all weeds removed prior to planting. This will help give this delicate crop a competitive advantage. Plough and sow early to avoid weed competition.

Competitive Cropping and Good Husbandry

Linseed may be broadcast seeded using 30-50 kg/ha depending upon the variety. It can also be row planted using 25-35 kg/ha and 20 cm between rows. Broadcasting is an easier and faster way to plant; however, row planting makes weeding faster. Seeds should be sown 1-2 cm deep and care should be taken not to cover the seeds too deeply. Sowing usually takes place between mid-June to the first week of July.

Number of Weedings

The number of handweedings will depend on the variety, soil moisture, temperature, and how well the seedbed was prepared. Generally, one handweeding is sufficient. Two handweedings may be required under very weedy conditions, when a short-statured, less branched variety is grown, or in higher rainfall areas.

Handweeding

This is the major weed control method recommended. Handweed once around 3 weeks after planting. Follow with a second handweeding if needed about 3 weeks later, depending upon how fast the weeds grow. Try to avoid competition.

Herbicides

Although herbicides are not the recommended weed control
Guide to herbicides used in linseed

<table>
<thead>
<tr>
<th>HERBICIDE</th>
<th>TRADE NAME &amp; FORMULATION</th>
<th>DOSE PRODUCT</th>
<th>CROP STAGE</th>
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<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td># bromoxyll</td>
<td>Bromital (480 g/iter EC)</td>
<td>0.8</td>
<td>Post emergence when 8-15 cm tall</td>
<td>Post emergence before 4 leaf stage</td>
<td>Many annual broad-leaved weeds.</td>
<td>Some leaf burn and retarded growth may occur but the crop will recover.</td>
</tr>
<tr>
<td># barban</td>
<td>Carbyne (125 g/iter EC)</td>
<td>2.2-3.8</td>
<td>Post emergence</td>
<td>Post emergence at 2 leaf stage</td>
<td>Wild oats.</td>
<td>Do not mix with other herbicides. Apply at precise stage.</td>
</tr>
<tr>
<td># dalapon</td>
<td>Dowpon, etc. (740 g/iter SP)</td>
<td>1.1-2.0</td>
<td>Post emergence just after emergence</td>
<td>Post emergence when grasses are small</td>
<td>Annual grasses.</td>
<td>Can be combined with other herbicides such as MCPA.</td>
</tr>
<tr>
<td># MCPA</td>
<td>U-46 Fluid (625 g/iter AS)</td>
<td>0.6-0.9</td>
<td>Post emergence when 5 cm to budding with best results</td>
<td>Post emergence to young vigorously growing weeds</td>
<td>Many annual broad-leaved weeds.</td>
<td>Do not apply to fiber flax.</td>
</tr>
</tbody>
</table>

(415 g/iter EC) 1.0-1.3
### Guide to herbicides used in linseed

<table>
<thead>
<tr>
<th>HERBICIDE, TRADE NAME &amp; FORMULATION</th>
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</tr>
</thead>
<tbody>
<tr>
<td># MCPA + bromoxynil U-46 M Fluid + Brominal (480 + 625 g/liter)</td>
<td>0.6 + 0.4</td>
<td>Post emergence when 5 - 10 cm tall</td>
<td>Post emergence before 4 leaf stage</td>
<td>Broadleafed weeds.</td>
<td>Do not apply in hot temperatures. Do not apply to fiber flax.</td>
</tr>
<tr>
<td>(480 + 415 g/liter)</td>
<td>0.6 + 0.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

# Recommended in other countries in the region.
measure, herbicides that can be used safely in the crop are listed in the table in case production systems might benefit from this form of weed control in the future.

Noxious Weeds

Cuscuta spp., a parasitic weed, can be a problem in some areas. See specific recommendations for control of this weed in Chapter IV.

RAPSEED

Critical Weed-free Period

Rapeseed is most sensitive to competition in its early growth stages. If a competitive, fast growing variety is planted, then weed competition is minimized.

Land Preparation

Although traditionally land is ploughed once, two ploughings plus seed covering are recommended in order to have a better seedbed.

Competitive Cropping and Good Husbandry

Broadcast seeding is the traditional method of planting. The crop can also be row planted in 10 cm rows which will facilitate weeding using 10 kg seed/ha. Because relatively small areas are currently seeded to this crop, broadcast seeding is easier. This will encourage the crop by increasing its competitive advantage and shading the weeds quickly. Use the recommended seeding rate of 12-18 kg/ha. The best time to plant in most areas is between mid- to end of June. If planted too late the crop may be exposed to frost before it reaches maturity.

Number of Weedings

In most cases one weeding is sufficient. Thinning may be done at this time if necessary.

Handweeding or Hoeing

Remove weeds 3 weeks after planting. If a competitive variety is used with broadcast seeding, only one weeding should be necessary.

Herbicides

Because of the limited acreage of this crop in the peasant
# Guide to herbicides used in rapeseed

<table>
<thead>
<tr>
<th>HERBICIDE, TRADE NAME &amp; FORMULATION</th>
<th>DOSE PRODUCT LITERS/HA</th>
<th>CROP STAGE</th>
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</tr>
</thead>
<tbody>
<tr>
<td>* alachlor (Lasso) (480 g/liter EC)</td>
<td>3.1</td>
<td>Pre-emergence</td>
<td>Pre-emergence</td>
<td>Many annual grasses and some broadleaved weeds.</td>
<td>Moist soil is needed within 10 days after application.</td>
</tr>
<tr>
<td>* napropamide (Devrinol) (500 g/kg UP)</td>
<td>3.0</td>
<td>Pre-emergence</td>
<td>Pre-emergence</td>
<td>Annual grasses and broadleaved weeds.</td>
<td></td>
</tr>
</tbody>
</table>

* Recommended by Institute for Agricultural Research
sector, herbicides are not presently recommended. Herbicides may be useful for commercial growers. There has not been extensive research done for Ethiopia in this area.

Intercropping

Rapeseed can be and is intercropped into maize, sorghum, and less frequently, teff. If it is a crop of secondary importance, it should receive any weed control which is applied to the main crop.

SUNFLOWER

Critical Weed-free Period

Sunflower is most sensitive to competition 4-8 weeks after planting. After this period, sunflower is very competitive.

Land Preparation

Prepare a good seedbed which is free of weeds and crop residues.

Competitive Cropping and Good Husbandry

Sunflower is relatively tolerant of drier conditions, and depending on the maturity time of the variety, can be planted later in the season. It does not tolerate waterlogged conditions. Row planting is recommended with 75 cm between rows and 30 cm between plants in the row. Seeding rate is 20-30 kg/ha. The crop can be overseeded and thinned later to the correct population density.

Number of Weedings

Two weedings are usually sufficient, the first 20-30 days after planting and the second 30-60 days after planting. If the variety is long season and there is considerable weed growth, weed a third time.

Handweeding and Hoeing

These two methods can be used, but it is more efficient to combine them with mechanical cultivation using tractor or animal-drawn implements in the row-seeded crop. These can also supplement herbicide use.

Mechanical Weeding with Tractor or Animal-Drawn Implements

Interrow cultivation can greatly speed up weeding. Implement in a similar way to maize.
Rotation

Sunflowers are a useful crop for rotational purposes. It can be used in rotation with cereals, particularly wheat and barley, where there are severe grass problems. It is also useful as a trap crop for Striga control. Sunflower will stimulate Striga to germinate but will not be attacked by it. This technique is useful for light infestations of Striga only.

Noxious Weeds

Orobanche spp. can be problematic in sunflower. See the section on Orobanche control.

Herbicides

Although herbicides are not presently recommended for weed control in this crop, the herbicides which are selective will be presented in case they are to be used in the future.

SESAME

Critical Weed-free Period

Sesame grows very slowly and is susceptible to weed competition particularly in the early stages of growth. The competitive ability of the crop in later stages depends upon the stature of the variety, that is, how tall and bushy it is.

Land Preparation

Well-prepared land is essential and contributes to early weed control when weeding by other methods is difficult. Prepare the land in time so that the crop can be seeded as soon as the rains begin. This will take advantage of the available moisture as well as eliminate competition from weeds which may be germinating before the crop. If there is a delay in planting after ploughing, and some weeds have started germinating, harrow or replough the land just before seeding. In some areas where there are very heavy showers, ridging or making a rough surface may help to prevent soil erosion and capping. Remove any perennial weeds during land preparation and before planting.

Competitive Cropping and Good Husbandry

Although sesame is usually broadcast seeded, row planting can assist in weeding when there is heavy weed pressure. If row planting is used, rows 30 cm apart and a seed rate of 5
Guide to herbicides for use in sunflower

<table>
<thead>
<tr>
<th>HERBICIDE, TRADE NAME AND FORMULATION</th>
<th>DOSE PRODUCT</th>
<th>CROP STAGE</th>
<th>WEED STAGE</th>
<th>WEEDS CONTROLLED</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>*# alachlor Lasso (480 g/liter EC)</td>
<td>3.6</td>
<td>Pre-emergence</td>
<td>Pre-emergence</td>
<td>Most annual grasses and some annual broadleafed weeds.</td>
<td>Moist soil within 10 days. Use lower dose on sandy soils.</td>
</tr>
<tr>
<td># fluazifop-butyl Fusilade (125 g/liter EC)</td>
<td>3.0</td>
<td>Post emergence before canopy closure</td>
<td>Post emergence to actively growing weeds</td>
<td>Many annual grasses and some control of perennial grasses depending on the species.</td>
<td>Use with other herbicides to control broadleafed weeds.</td>
</tr>
<tr>
<td># metolachlor Dual (720 g/liter EC)</td>
<td>1.5-2.5</td>
<td>Pre-emergence</td>
<td>Pre-emergence</td>
<td>Most annual grasses and some broadleafed weeds.</td>
<td>Inactive in dry conditions.</td>
</tr>
<tr>
<td># pendimethalin Stomp (500 g/liter EC)</td>
<td>1-4</td>
<td>Pre-emergence</td>
<td>Pre-emergence</td>
<td>Many annual grasses and some broadleafed weeds.</td>
<td>Inactive in dry conditions.</td>
</tr>
<tr>
<td># prometryne Gesagard (500 g/liter FU)</td>
<td>2.4-3.2</td>
<td>Pre-emergence at or within 2 days of planting.</td>
<td>Pre-emergence and early post emergence to seedlings.</td>
<td>Annual broadleafed weeds and some grasses.</td>
<td>Do not apply to sandy soils. Moist soil is needed.</td>
</tr>
</tbody>
</table>

* Recommended by Institute of Agricultural Research  # Recommended in other countries of the region.
kg/ha are recommended. However, if interrow cultivation with animals or tractors is used, the row spacing needs to be increased to 70-80 cm in order to prevent damage to the seedlings. If broadcast seeded, the crop can be overseeded and then thinned to 10 cm between plants to make it easier to handweed or hoe and to decrease competition for moisture between the plants. Plant only on well-drained soil because sesame is very sensitive to waterlogging. It can tolerate low fertility conditions as well as sandy soils.

Number of Weedings

Two weedings are normally required to keep the crop weedfree; however, if the weed infestation is high and/or the crop variety not very competitive, a third weeding may be necessary. Perform all weeding before the crop canopy closes.

Handweeding and Hoeing

Because the crop is very small, it is impractical to begin handweeding or hoeing until the crop is 15-20 cm tall. The seedlings are shallow rooted and very sensitive to disturbance; thus handweeding or hoeing must be done very carefully. This is one reason why overseeding is recommended because there will inevitably be some thinning related to damage when weeding.

Cultivation

Cultivation can be used with row planting if done carefully. This method makes earlier weeding possible compared to handweeding. This eliminates competition at the crucial stage. Cultivation should be shallow in order to avoid root damage.

Herbicides

Herbicides can be useful to control weeds early in the crop life through the critical period and help to avoid any damage to the crop which occurs in mechanical weed removal. The economics of using herbicides is questionable for most small farmers until improved crop production practices which raise the yield potential are adopted.

GROUNDNUT

Critical Weed-free Period

Groundnuts are sensitive to early weed competition because of their initial slow growth. They are also sensitive to
# Guide to herbicides used in sesame

<table>
<thead>
<tr>
<th>HERBICIDE &amp; TRADE NAME</th>
<th>DOSE PRODUCT</th>
<th>CROP STAGE</th>
<th>WEED STAGE</th>
<th>WEEDS CONTROLLED</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>*# alachlor Lasso</td>
<td>4.0</td>
<td>Pre-emergence</td>
<td>Pre-emergence</td>
<td>Many annual grasses, some control of sedges.</td>
<td>Use lower dose on sandy soils. Moisture is needed within 10 of application.</td>
</tr>
<tr>
<td></td>
<td>(480 g/liter EC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*# diuron Karmex</td>
<td>0.6-1.8 Kg</td>
<td>Pre-emergence</td>
<td>Pre-emergence</td>
<td>Many annual weeds.</td>
<td>Moist soil is needed within 3 - 4 days of application. Injury may occur at high doses.</td>
</tr>
<tr>
<td>Diment</td>
<td>(800 g/kg WP)</td>
<td></td>
<td>or early post emergence to seedling weeds.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Recommended by Institute for Agricultural Research

# Recommended for use in other countries of the region.
weed interference during pegging. Generally, yields are reduced if weeds are present 4-8 weeks after planting and perhaps longer under dry conditions. Crop competitiveness depends on the variety and population levels, among other factors.

Land Preparation

Land should be well-prepared, free of crop and weed residues. Well-drained, fertile, friable, sandy loams are suitable for groundnuts. They can be grown on ridges which are 45 cm apart. It is important that the seedbed is smooth and free from clods. Plough two or three times. Destroy any perennial grass or sedge weeds during the dry season.

Competitive Cropping and Good Husbandry

Avoid waterlogged areas; if it is a problem grow the crop on ridges. It is often advisable to plant near the end of the rains so that pods mature and are harvested during the dry season. Groundnuts can be broadcast seeded or grown in rows. It is important to get a good stand which will be competitive with weeds but which also helps to avoid rosette virus. Row planting is recommended to make harvesting and weeding operations faster and easier. Row spacing depends upon the variety, whether it is spreading or upright. Use 50-60 cm for upright types and 80 cm for spreading types with 10 cm between plants in the row. Seeding rate is 60-80 kg/ha.

Number of Weedings

Groundnuts are not competitive and need at least three weedicings. Do not cultivate after 50% flowering because this will damage the developing pods.

Handweeding and Hoeing

If weeding is done using these methods, row planting can make the operation much less tedious. Use shallow cultivations because this crop is very sensitive to root damage. Combine these methods with herbicides to kill any escaping weeds. Perform the first handweeding 30 days after emergence, the second between 40-50 days and the third between 60-80 days after emergence.

Interrow Cultivation

If row planted, shallow interrow cultivation can quickly get rid of weeds. It must be combined with handweeding in the row. Use the same timings as for manual weed control.
### Guide to herbicides used in groundnut

<table>
<thead>
<tr>
<th>HERBICIDE TRADE NAME AND FORMULATION</th>
<th>DOSE PRODUCT LITERS/HA</th>
<th>CROP STAGE</th>
<th>WEED STAGE</th>
<th>WEEDS CONTROLLED</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td># alachlor Lasso (480 g/liter EC)</td>
<td>3.5-5.0</td>
<td>Pre-emergence</td>
<td>Pre-emergence</td>
<td>Annual grasses and some broadleafed weeds.</td>
<td>Apply to moist soil. Plant at least 5 cm deep.</td>
</tr>
<tr>
<td># bentazon Basagran (480 g/liter EC)</td>
<td>2.0</td>
<td>Post emergence at 1-4 trifoliate stage</td>
<td>Post emergence at 3-5 leaf stage</td>
<td>Many annual broadleafed weeds.</td>
<td>Do not apply under hot temperatures, &gt;21 degrees C. Do not apply if rain is expected within 8 hrs.</td>
</tr>
<tr>
<td># diclofop methyl Illopan (360 g/liter EC)</td>
<td>2.0-2.5</td>
<td>Post emergence at 1-4 leaf stage</td>
<td></td>
<td>Many annual grasses.</td>
<td></td>
</tr>
<tr>
<td># fluazipop butyl Fusilade (125 g/liter EC)</td>
<td>2.0</td>
<td>Post emergence before canopy closes</td>
<td>Post emergence to actively growing weeds; perennials at least 3 leaves per shoot</td>
<td>Many annual and perennial grasses.</td>
<td>Use higher rate for controlling perennials. Cultivation prior to spraying followed by resprouting may give better control.</td>
</tr>
</tbody>
</table>

141
Guide to herbicides used in groundnut

<table>
<thead>
<tr>
<th>HERBICIDE, TRADE NAME AND FORMULATION</th>
<th>DOSE PRODUCT</th>
<th>CROP STAGE</th>
<th>WEED STAGE</th>
<th>WEEDS CONTROLLED</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td># metolachlor</td>
<td>1.5-2.5</td>
<td>Pre-emergence</td>
<td>Pre-emergence</td>
<td>Annual grasses and few broadleaves.</td>
<td></td>
</tr>
<tr>
<td>Dual (720 g/liter EC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong># terbutryne</strong></td>
<td>2.0</td>
<td>Pre-emergence</td>
<td>Pre-emergence</td>
<td>Many annual broad-leaved weeds and some grasses.</td>
<td>Do not use on low clay soils. Apply to moist soil.</td>
</tr>
<tr>
<td>Igran (500 g/liter EC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Recommended by Institute for Agricultural Research

# Recommended for use in other countries in the region.
Herbicides

Herbicides can be used economically in this crop because handweeding is intensive. It is usually necessary to combine herbicides with a late handweeding.
Weed Control in Pulse Crops

LENTILS

Critical Weed-free Period

Normally, lentils are very sensitive to weed competition from the early growth stages up to start of flowering. Yield losses up to 50% can occur if lentils are left unweeded. However, weed competition can be avoided by planting lentils on residual moisture at the end of the main rainy season.

Land Preparation

Have land well prepared and free from weeds at sowing time. Two ploughings are recommended, the first during the short, early rains and the second after the main rains begin.

Competitive Cropping and Good Husbandry

Lentils are planted both in the beginning and at the end of the main rainy season; the latter is practiced mainly on black clay soils. However, early planting (last week of June to mid-July) is advantageous. Lentils do not tolerate waterlogged conditions so select a well-drained field. Planting can be broadcast or row seeded. If rows are used place them 20-22.5 cm apart. The recommended seeding rate is 50-75 kg/ha depending upon the seed size (65-75 kg/ha for large seeds and 50-60 kg/ha for small seeds). Rotate lentils with cereals, planting lentils every two years.

Number of Weedings

If land preparation and weed removal have been done completely before planting, only one handweeding for early sown crops and no weeding for the late sown crop will be necessary. However, if there is early weed competition in the late season crop, one handweeding will be needed. If there is rainfall late in the season, a second weeding may be necessary, but this is rare.

Handweeding

Handweeding is the method commonly used for removing weeds. If weeding is needed, weed 2-3 weeks after emergence. Lentils can be easily damaged by the disturbance caused by continuous handweeding.

Herbicides

Very little experimental work has been done on herbicides.
Guide to herbicides used for lentil

<table>
<thead>
<tr>
<th>HERBICIDE TRADE NAME AND FORMULATION</th>
<th>DOSAGE PRODUCT</th>
<th>CROP STAGE</th>
<th>WEED STAGE</th>
<th>WEEDS CONTROLLED</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td># diclofop methyl illoxa (360 g/liter EC)</td>
<td>2.0</td>
<td>Post emergence</td>
<td>Post emergence</td>
<td>Annual grasses.</td>
<td>Do not apply if grasses are past the 4 leaf stage.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>at 3 trifoliate stage</td>
<td>at 1-4 leaf stage when stage of grass is 5-6 cm tall</td>
<td>Annual grasses.</td>
<td>Do not apply if grasses are past the 4 leaf stage.</td>
</tr>
<tr>
<td># fluazifop butyl Fusilade (125 g/liter EC)</td>
<td>2.0</td>
<td>Post emergence</td>
<td>Post emergence</td>
<td>Annual and perennial grasses.</td>
<td>Avoid drift. Do not mix with other herbicides.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>at 3 trifoliate stage</td>
<td>at 2-4 leaf stage</td>
<td>Annual and perennial grasses.</td>
<td>Avoid drift. Do not mix with other herbicides.</td>
</tr>
<tr>
<td>* prometryn Gesagard (500 g/liter FW)</td>
<td>4.0</td>
<td>Pre-emergence</td>
<td>Pre-emergence</td>
<td>Many broadleaf and some annual grass weeds.</td>
<td>Do not use on light sandy soils.</td>
</tr>
</tbody>
</table>

* Recommended by Institute for Agricultural Research
# Recommended by other countries in the region.
for lentil weed control in Ethiopia. Generally, herbicides are not recommended for peasant agriculture at this time unless the crop is grown on a large commercial scale.

CHICKPEA

Critical Weed-free Period

Chickpea is sensitive to early competition and is less competitive than lentils; however, because it is sown late in the season and grown on residual moisture, it seldom encounters much weed competition. Yield reductions in fields which were not weeded have been about 30%.

Land Preparation

Land should be properly prepared and weed free at planting but good land preparation is not as crucial as it is for other crops. Plough similar to lentils. Twice is usually sufficient.

Competitive Cropping and Good Husbandry

Chickpea is commonly planted at the end of the rainy season and does well on the residual moisture in black clay soils. Planting from the last week of August to the first week of September can increase chickpea yields by 25-50%. Like lentils, chickpea will not tolerate waterlogged soils. Usually the crop is broadcast seeded; however, row planting with 30 cm between rows and 10 cm between plants is recommended. The recommended seed rate is 65-80 kg/ha for both broadcast and row planted depending upon the seed sizes (less for smaller seeds and more for larger seeds).

Number of Weedings

If land preparation and weed removal have been complete before planting, no weeding should be necessary especially in late planted chickpea. However, if there is early weed competition one handweeding will be needed. If there is rainfall occurring late in the season, a second handweeding may be necessary, however, this is rare. Keep the crop weed free until the canopy covers the soil.

Handweeding

Handweeding is the method commonly used for removing weeds if it is necessary. If weeding is needed, weed 2-3 weeks after emergence. This crop can be easily damaged by the disturbance caused by continuous handweeding.
Herbicides

Very little experimental work has been done on herbicides for chickpea weed control in Ethiopia. Generally, herbicides are not recommended for peasant agriculture at this time unless grown for large scale commercial production.

FABA BEAN

Critical Weed-free Period

Faba beans are sensitive to weed competition from the early establishment to the early flowering stage. The average yield reduction due to no weeding is 24%. If not weeded during the first 4, 7, or 12 weeks after sowing, the yield reductions were 13%, 16%, and 22% respectively.

Land Preparation

Two to three ploughings are recommended in order to have a suitable weed-free seedbed. Early rather than late ploughing is recommended for weed control.

Competitive Cropping and Good Husbandry

Although faba bean is commonly broadcast seeded, row planting is recommended because this will make weeding and other cultural operations such as spraying faster and easier. Where faba beans are intercropped with field peas, farmers usually prefer to broadcast seed; however, it should be possible to intercrop within the rows. For both broadcast and row seeding use 200 kg/ha for small-seeded varieties and 250 kg/ha for large-seeded varieties. The recommended row spacing is 40 cm between rows and 5 cm between plants. Crop rotation with cereals is very important to avoid disease and insect problems. Grow faba beans in the same place once every 3 years. Plant on well-drained soils. The recommended planting time is end of June to mid-July.

Number of Weedings

Normally farmers do not weed this crop; however, it is very sensitive to weed competition and requires two weedings, one 3-4 weeks after emergence and the second 6-8 weeks after emergence.

Handweeding and Hoeing

Presently, handweeding and hoeing are the major methods used to keep this crop weedfree during the critical period.
Guide to herbicides for use in faba beans and field peas

<table>
<thead>
<tr>
<th>HERBICIDE, TRADE NAME AND FORMULATION</th>
<th>DOSE PRODUCT</th>
<th>CROP STAGE</th>
<th>WEED STAGE</th>
<th>WEEDS CONTROLLED</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>* cyanazine</td>
<td>2.5 Kg</td>
<td>Pre-emergence</td>
<td>Pre-emergence</td>
<td>Annual broadleaved weeds and some grasses.</td>
<td>Short residual life.</td>
</tr>
<tr>
<td>Bladex (800 g/Kg UP)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>* fluazifop butyl</td>
<td>2.0</td>
<td>Post emergence</td>
<td>Post emergence</td>
<td>Annual and perennial grasses.</td>
<td></td>
</tr>
<tr>
<td>Fusilade (125 g/liter EC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>* pendimethalin</td>
<td>4.0</td>
<td>Pre-emergence</td>
<td>Pre-emergence</td>
<td>Annual grasses and some broadleaved weeds.</td>
<td></td>
</tr>
<tr>
<td>Stomp (500 g/liter EC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>* prometryn</td>
<td>4.0</td>
<td>Pre-emergence</td>
<td>Pre-emergence</td>
<td>Many broadleaved and some annual grass weeds.</td>
<td>Do not use on light sandy soils.</td>
</tr>
<tr>
<td>Gesagard (500 g/liter FU)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># sethoxydim</td>
<td>0.3</td>
<td>Post emergence</td>
<td>Post emergence</td>
<td>Annual grass weeds.</td>
<td>Apply to moist soil. Avoid rainfall right after application.</td>
</tr>
<tr>
<td>Poast (750 g/liter SP)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Recommended by Institute for Agricultural Research
# Recommended for use in other countries in the region.
Because labor for weeding this crop is usually competing with weeding of teff and wheat, row planting is suggested to speed up the weeding process.

Herbicides

Herbicides, combined with handweeding where necessary, may help to reduce the competition for labor, particularly at the early growth stages.

FIELD PEA

Critical Weed-free Period

Field peas are not as sensitive to early competition as many of the other pulses. However, yield reduction can occur if there is no attention to weed control. The loss figures for Ethiopia are variable, from 15% to 67% when there was no weeding.

Land Preparation

Traditionally, farmers prepare a very rough seedbed. In order to avoid competition, particularly if little effort is spent on tedious handweeding, more attention must be given to land preparation. It is recommended that land should be ploughed once before sowing.

Competitive Cropping and Good Husbandry

Peas can be broadcast seeded, as traditionally practiced, or row planted, which is more tedious but aids in weeding where weeds are particularly competitive. For broadcast seeding, use 150 kg/ha of seed. Try to establish a dense seeding so the plants will be more competitive. If row planted, establish the rows 20 cm apart with 5 cm between plants. Plant 100-150 kg/ha so the population level is between 450,000-700,000 plants/ha, when germinating properly. There is a large variation in variety competitiveness. The short habit varieties definitely require weed-free conditions for their optimal growth and development. Choose a competitive variety if possible.

Number of Weedings

If the well-prepared seedbed is immediately followed by broadcast seeding, no additional weeding may be necessary if the crop is vigorous and fast growing. In situations where weed infestation appears to be heavy or troublesome, weeding once, 3-4 weeks after emergence is sufficient. For short habit varieties 2 weedings may be desirable.
Handweeding or Hoeing

Handweeding is the best method of weed control for this crop at this time but it is tedious. Row seeding helps to make handweeding or hoeing easier and faster. Avoid weeding after the beginning of flowering. After this time, weeding will cause crop damage. Try to weed before the crop plants become entwined.

Herbicides

Although at the present time, it is probably not economic to use herbicides, these chemicals can be useful in weed control. Because the crop is tedious and difficult to handweed, farmers harvest reduced yields by not weeding when they should. There may be some situations where herbicides might be practical and economic. See recommendations made for faba beans; they are the same for field peas.

HARICOT BEAN

Critical Weed-free Period

Beans should be kept weedfree from 4-6 weeks after planting or when canopy development is sufficient to suppress weeds. This period depends upon the competitiveness of the variety and its spacing. The more spreading types, if planted at close spacing, will have a shorter critical period. Yield losses for row-planted beans which have received no weeding vary from 36% to as high as 94%.

Land Preparation

Prepare a smooth, flat seedbed free from weeds by ploughing 2-3 times. Control perennial grass weeds as much as possible by removing during the land preparation stage. Rotation with crops where previous weed control was good will help to reduce weeds competing with beans.

Competitive Cropping and Good Husbandry

Beans can be broadcast or row seeded. Careful broadcast seeding ensuring fairly uniform spacing at a high seeding rate, using clean seed of a competitive variety, may eliminate or decrease the need for weeding if there are not many noxious or fast growing weeds present. If row seeding, use 40 cm between rows and about 7 cm between plants in the row, using a seeding rate of 60-70 kg/ha for small-seeded varieties (e.g. Mexican 142) and up to 120 kg/ha of seed for large-seeded varieties. For broadcast planting, higher seed
rates may be used if little weeding is to be done and provided that there is enough soil moisture to sustain a high plant population. Planting time is usually July. Row planting helps to reduce the amount of seed and makes weeding and harvesting easier. Rotate with other crops and only grow in the same area every 3-4 years to avoid disease problems. Selection of undamaged, well-filled and non-shrunken seeds that show no discoloration reduces the incidence of seed-transmitted disease, such as common bacterial blight.

Intercropping

Intercropping is commonly practiced with field peas into faba beans or other crops. Use the weed control recommendations for the major crop in this case. Beans can be successfully intercropped in either maize or sorghum. Although simultaneous planting may increase the yield of beans, this makes weeding difficult; planting beans at the time of the first maize weeding may be better. Usually the large-seeded types (red, black or speckled) are used for this purpose. The white, small-seeded varieties are usually used for commercial production in pure stand.

Number of Weedings

One or two handweedings are recommended for row-seeded beans, the first 3-4 weeks after planting and the second 2-3 weeks later, if needed. If a second weeding is done, be careful to avoid damage to the beans. If broadcast seeded with a competitive variety, one weeding may be sufficient.

Handweeding and Hoeing

Handweeding is laborious but may be the only method available. Hoeing can speed up weed control; however, unless shallow, can injure the crop roots, which are sensitive to disturbance, and care is also needed to avoid wounding the main stem, which can encourage pest attack. Handweeding and hoeing can be successfully combined with herbicides.

Cultivations

Shallow mechanical using a hoe or tractor drawn cultivator can be used for weed control in row-planted crops. Start cultivating 4 weeks after planting, when the beans are large enough so that they are not buried. Try to throw a layer of soil into the row to smother any in-row weed seedlings. Do not cultivate if the weeds are large because this will not achieve good weed control and will injure the beans by disturbing too much soil near them.
## Guide to herbicides used in haricot beans

<table>
<thead>
<tr>
<th>HERBICIDE, TRADE NAME AND FORMULATION</th>
<th>DOSE PRODUCT LITERS/HA</th>
<th>CROP STAGE</th>
<th>WEED STAGE</th>
<th>WEEDS CONTROLLED</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td># alachlor Lasso (480 g/liter EC)</td>
<td>4.0-5.0</td>
<td>Pre-emergence</td>
<td>Pre-emergence</td>
<td>Annual grasses and some broadleafed weeds.</td>
<td>Apply to moist soil.</td>
</tr>
<tr>
<td># bentazon Basagran (480 g/liter EC)</td>
<td>2.0</td>
<td>Post emergence at 2-5 trifoliate stage</td>
<td>Post emergence at 3-5 leaf stage</td>
<td>Many annual broadleafed weeds.</td>
<td>Do not apply under hot temperatures, &gt;21 degrees C. Do not apply if rain expected within 8 hrs.</td>
</tr>
<tr>
<td># fluazifop butyl Fusilade (125 g/liter EC)</td>
<td>2.0</td>
<td>Post emergence before canopy closes.</td>
<td>Post emergence to actively growing weeds. Perennials- at least 3 leaves per shoot</td>
<td>Many annual and perennial grasses.</td>
<td>Use higher rates for controlling perennials. Cultivation prior to spraying followed by resprouting may give better control.</td>
</tr>
<tr>
<td># linuron Afaion (500 g/kg WP)</td>
<td>2 Kg</td>
<td>Pre-emergence</td>
<td>Pre-emergence</td>
<td>Annual broadleafed weeds and some grasses.</td>
<td>Plant crop at least 2-5 cm deep. Do not apply to sandy soil or where heavy rainfall is likely. Moisture is needed for activation.</td>
</tr>
</tbody>
</table>
Guide to herbicides used in haricot beans

<table>
<thead>
<tr>
<th>HERBICIDE TRADE NAME AND FORMULATION</th>
<th>DOSE PRODUCT LITERS/HA</th>
<th>CROP STAGE</th>
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<th>WEEDS CONTROLLED</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td># metobromuron</td>
<td>2.2-3.5 kg</td>
<td>Pre-emergence</td>
<td>Pre-emergence</td>
<td>Annual broadleafed weeds and some grasses.</td>
<td>Plant seeds 3 cm deep. Apply to moist soil.</td>
</tr>
<tr>
<td>Patoran</td>
<td>(500 g/kg WP)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># metobromuron + metolachlor</td>
<td>5.0-6.0</td>
<td>Pre-emergence</td>
<td>Pre-emergence</td>
<td>Broadleafed weeds and many grasses.</td>
<td>Use as above.</td>
</tr>
<tr>
<td>Galex</td>
<td>(250 - 250 g/liter EC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># metolachlor</td>
<td>2.0-3.5</td>
<td>Pre-emergence</td>
<td>Pre-emergence</td>
<td>Annual grasses and a few broadleaves.</td>
<td></td>
</tr>
<tr>
<td>Dual</td>
<td>(720 g/liter EC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># pendimethalin</td>
<td>1.2-4.7</td>
<td>Pre-emergence</td>
<td>Pre-emergence</td>
<td>Annual grasses and a few broadleaves.</td>
<td>Incorporate in dry conditions. Can use in herbicide mixtures.</td>
</tr>
<tr>
<td>Stomp</td>
<td>(500 g/liter EC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Recommended by Institute of Agricultural Research  # Recommended by other countries in the region.
Herbicides

Herbicides may be too costly in most cases unless beans are being grown on a large scale and the crop has a high potential yield due to favorable rainfall and soils. Herbicides, alachlor in particular, have been successfully combined with a follow-up handweeding.

Prevention

Use clean, weed-free crop seed. During harvesting, try to avoid combining weeds and the crop. Pull and remove the weeds so that threshing is with weed-free plants. Use a clean threshing area.

SOYBEAN

Critical Weed-free Period

The critical time of competition is from the early growth period up to flowering. Yield reductions have been reported for periods of 4, 8, and 12 weeks of no weeding to be 56%, 50%, and 75% respectively.

Land Preparation

Three ploughings are recommended to produce a fine seedbed. Do the last ploughing just before planting. Try to control any problem weeds during this period prior to planting. Soybean can be grown using minimum tillage, however this technology has not been tested in Ethiopia.

Competitive Cropping and Good Husbandry

Plant soybean early in the main rains because it is sensitive to drought. Sowing date is dependent on the area and variety. It is recommended to use row planting with the spacing of 60 cm between rows and 5 cm between the plants in the row. Plant 60 kg/ha. Narrow rows help make the crop more competitive with weeds as well as facilitating weeding.

Number of Weedings

Two to three weedings are necessary to keep the crop weed-free during the critical period.

Handweeding or Hoeing

Perform the first handweeding when the crop reaches the 2-4 leaf stage. The second weeding should be 2-3 weeks later and the third if needed should be just before flowering. If
using a hoe, cultivate to a shallow depth because this crop
is sensitive to root damage. If herbicides are used, they
may have to be followed by one handweeding because
herbicides will not give full season control.

Interrow Cultivation

This method is difficult using animal-drawn implements
because of the close spacing of the rows; however, if
tractor cultivation is available, the use of rotary hoes
starting at the 2-4 leaf stage, the second 25 days after
planting, and the third if needed just before flowering.
Make sure that all cultivations are shallow.

Herbicides

See table for herbicides.
## Guide to herbicides for use in soybeans

<table>
<thead>
<tr>
<th>HERBICIDE, TRADE NAME AND FORMULATION</th>
<th>DOSE PRODUCT LITERS/HA</th>
<th>CROP STAGE</th>
<th>WEED STAGE</th>
<th>WEEDS CONTROLLED</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td># alachlor Lasso (480 g/liter EC)</td>
<td>3.5-5.0</td>
<td>Pre-emergence</td>
<td>Pre-emergence</td>
<td>Annual grasses and some broadleafed weeds.</td>
<td>Apply to moist soil.</td>
</tr>
<tr>
<td># bentazon Basagran (480 g/liter EC)</td>
<td>2.0</td>
<td>Post emergence</td>
<td>Post emergence</td>
<td>Many annual broadleafed weeds.</td>
<td>Do not apply under hot temperatures, &gt;21 degrees C. Do not apply if rain expected within 8 hrs.</td>
</tr>
<tr>
<td># diclofop methyl Illozan (360 g/liter EC)</td>
<td>2.0-2.5</td>
<td>Post emergence</td>
<td>Post emergence</td>
<td>Many annual grasses.</td>
<td></td>
</tr>
<tr>
<td># fluazifop butyl Fusilade (125 g/liter EC)</td>
<td>2.0</td>
<td>Post emergence</td>
<td>Post emergence</td>
<td>Many annual and perennial grasses.</td>
<td>Avoid using higher rates on soybeans. Cultivation prior to spraying followed by re-sprouting may give better control.</td>
</tr>
</tbody>
</table>
## Guide to herbicides for use in soybeans

<table>
<thead>
<tr>
<th>HERBICIDE, TRADE NAME AND FORMULATION</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Linuron Afalon (500 g/Kg WP)</td>
<td>1.5-5.0 kg</td>
<td>Pre-emergence or directed post-emergence when 30 cm tall</td>
<td>Pre-emergence or early post emergence to young weeds</td>
<td>Annual broadleafed weeds and some grasses.</td>
<td>Sow crops at least 2-5 cm deep. Apply to moist soil. Do not use on light soils.</td>
</tr>
<tr>
<td>Metolachlor Dual (720 g/Liter EC)</td>
<td>1.5-2.5</td>
<td>Pre-emergence</td>
<td>Pre-emergence</td>
<td>Annual grasses and a few broadleaves.</td>
<td></td>
</tr>
</tbody>
</table>

* Recommended by Institute for Agricultural Research.  
# Recommended in other countries in the region.
Weed Management in Cash Crops Grown by Small Farmers

COFFEE

Critical Weed-free Period

Yield reductions can occur, particularly in unshaded, young coffee and recently stumped coffee, if weeds are not controlled. Young coffee is weakened and irreparably damaged by the weak establishment caused by poor weed control, especially if rhizomatous grasses and sedges are present.

Weeds in coffee compete primarily for water and nutrients. Their presence, particularly near the coffee tree, will make fertilizer or manure use inefficient. Nitrogen fertilizer applied with poor weed control enhances the vigor of the weeds and enables them to compete more effectively. Some weeds such as couch grass (Digitaria abyssinica) are thought to have allelopathic effects. The weed is able to produce a toxic chemical from its roots which can reduce coffee growth. In Ethiopia, minimum weeding reduced coffee yield by 62%. Weed control from the nursery to the field is vital and must continue thereafter on a regular, routine basis. Quality as well as yields suffer due to weed competition.

Land Preparation

In areas not under forest, a thorough land preparation is necessary prior to establishing new coffee plantings. Several ploughings or cultivations will be necessary for good preparation. This can be accomplished by ploughing with oxen, by hand digging or a combination. The soil should be weed-free, especially of perennial weeds, when planting takes place. If perennial weeds are present, land preparation should be done repeatedly during the dry season to help desiccate the underground rhizomes. Avoid cutting the rhizomes into small pieces unless a translocated herbicide is used, because this will make the problem worse.

Because rhizomatous grasses are very difficult to remove after coffee establishment and are very competitive, extra care should be made to remove these from the area before planting. This is particularly true where translocated herbicides are not being used. It will probably be necessary to start cultivations one year in advance in order to achieve good control of perennials and sedges before planting. A suggested schedule for this circumstance is to begin ploughing mid-November to mid-March the first year. Complete the eradication of perennial grasses in October to mid-January the second year, and proceed with planting at the onset of the rains (March-April for most areas).
perennial grasses are particularly problematic and require a lot of labor for control, accompany land preparation with a non-selective herbicide. Maize or other cereals which receive good weed control can precede the establishment of coffee by two years, in order to decrease weeds.

If there is a potential for erosion, establish terraces with mulch species on the terrace edges. The mulches also can be used to reduce weed competition. Species such as: *Pennisetum purpureum* (Elephant or Napier grass), *Panicum antidotale* (Blue panic grass), *Chloris gayana* (Rhodes grass), and *Setaria anceps* (Nandi grass) have been used successfully in other areas of East Africa. The establishment of terraces and contour bunds is particularly important in drier areas where soil and water conservation is crucial. In wetter areas, soil conservation and drainage are of greater concern and these measures are equally important.

In forested areas, where there is abundant shade, there may be no need for ploughing because rhizomatous grasses and sedges will be absent. Slashing or using a non-selective herbicide to remove and kill any vegetation followed by planting hole preparation is sufficient.

Once the coffee is established, there may be a need for further land preparation for intercrops (live mulch or food crop species). Research shows that intercropping will reduce yields for some time; therefore this practice should be used only in certain circumstances. (See section below). Because coffee's shallow feeder roots are sensitive to being damaged by cultivation, care should be taken to avoid using deep cultivation in the area immediately under the canopy line. Use shallow cultivation in these areas if needed. Cultivation alone or combined with herbicides should be used to prepare a weed-free seedbed for the intercrops.

**Competitive Cropping and Good Husbandry**

Coffee seedlings should be in a good condition (the tap root should not be twisted, lateral roots should be well-developed, the seedling should be free of disease such as leaf rust) at the time of transplanting in order to enhance establishment. It is recommended that seedlings should be approximately 20-25 cm tall and 10-12 months old. A planting hole of 50 x 50 x 50 cm is commonly used; however, in drier areas there are better results if the hole is larger. The planting holes should be left open for a minimum of 3 months after digging. Mix some manure, compost, or organic matter with the top soil before planting. The recommended density (Coffee Improvement Project) is 3,800 plants/ha for high
rainfall areas and 2,500 for lower rainfall areas (such as in Haraghe). This population is accomplished by planting trees using 1.5 x 1.3 x 1.3 m spacing (high rainfall) and 2.5 x 1.5 x 1.5 m (lower rainfall) in staggered rows. The rows are planted in sets of four with a 3 m service strip in between. Coffee requires good drainage so avoid planting on black Vertisols where there is poor drainage.

Follow the recommended practices for maintaining the coffee trees, keeping them well fertilized, insect pest and disease free. Proper pruning is necessary to achieve high yields, but traditionally farmers do not prune enough. Pruning should take place annually, immediately after the main harvest (around December-February in most areas). A multiple stem system is recommended. The operations include:

- removal of primary branches below 60 cm;
- removal of suckers;
- removal of secondary growth within 22 cm of the main stem;
- removal of secondary branches growing towards the stems, up or down;
- removal of interlocking branches;
- removal of secondary branches so that the arrangement on alternate sides of the primaries are up to a maximum of six per primary. Only two to four of the secondaries are allowed to carry a crop each year.

After the onset of the rains, the flush of growth (suckers) initiated by the rain should be removed periodically; it is a relatively small job. If not, there will be adverse inter-plant competition effects and the potential yield will be reduced.

For stumping, conversion, and changing of production cycle practices, refer to MTCD recommendations.

**Number of Weedings**

The frequency of cultivations depends upon the rainfall, temperature conditions, whether under forest, and length of growing season. The greater the rainfall and temperature, the greater number of weedings will be needed, especially where there are no shade trees. The amount of weed cover under shade is usually very little and therefore, less weeding is necessary because perennial grasses are rare in these conditions. Keep the coffee as weedfree as possible during active growth periods, berry formation, and maturity. At the time of this publication, there are no recommendation for the number of weedings for the different conditions represented by the coffee growing areas.
Handweeding and Hoeing

Deep cultivation should be avoided, particularly in the area immediately under and surrounding the coffee tree. Use handpulling or shallow cultivation with a fork-type implement. Hoeing will be less time consuming than handweeding and is recommended for most conditions, particularly when labor is in short supply. Hoeing large weeds, and prevents the effects of competition. Hoeing large weeds encourages chopping or digging rather than surface scraping. A small, light-weight hoe is recommended, if available. Many weeds can be used as mulch around the coffee bushes; however, there are some weeds such as Galinsoga parviflora, Digitaria abyssinica, Cynodon nlemfluensis, or Commelina sp. which will re-root easily under wet conditions and be sources of reinfestation. Remove them from the field after they are hoed or pulled and compost or burn them. The best time to cultivate is when the soil is moist, not too wet or too dry. This is sometimes difficult to achieve during the rainy season.

If labor or time is extremely limited or if there is a threat of soil erosion, concentrate the shallow hoeing or handweeding around the trees (under the canopy) or in the rows. Leave weedy strips of soft, broadleafed weeds only between the rows and use slashing to reduce seeding. Otherwise use mulch between the rows.

Slashing

This method is used in western Ethiopia where the major problems are broadleafed weeds and where the coffee bushes are grown under shade. Slashing can be used for well-established plantings, which will be harmed less than newly planted trees by competition. The main usefulness of this method is to maintain a ground cover in-between the rows of coffee rather than near the coffee trees.

It is not the preferred method for weed control, because under wet conditions weeds regrow very quickly. It is usually difficult to slash them early enough or enough times to ensure no competition. Slashing also tends to encourage weeds that are resistant to this practice, such as low growing perennial grasses (Cynodon and Digitaria sp.) and sedges, which are undesirable and difficult to control. If this method is used, make certain that weeds are slashed before seeding. This method will cause some yield reduction. This can be minimized by maintaining the area under the coffee tree canopy completely weedfree and keeping the slashed areas only between the rows. Tree injury can occur
by slashing carelessly and gashing the bark. These damaged areas can be an entrance for disease. Therefore, if slashing is used, care should be taken to avoid gouging the tree. The tree ring should always be kept weedfree and preferably mulched.

Living Mulch

Using living species between the rows of coffee is essentially the same as intercropping, although the plants are more permanent. Where coffee is the primary crop and where land for food crops is not limited, this method has less value. The establishment of a relatively uncompetitive, perennial leguminous forage species between the rows of coffee may have several advantages: it replaces more difficult to manage weed species with a potentially easy to manage species which may also be used as forage. If managed in strips 1 m from the coffee tree rows, it can help to reduce erosion, and perhaps supply some nitrogen to the coffee. Species selection is important but has not been experimented with extensively in Ethiopia to give definite recommendations at this time. Species such as Trifolium sp., Medicago sp., Desmodium sp. are suggested for evaluation before wide introduction to determine whether there are any site specific detrimental effects.

Species that are palatable to rodents or other wild animals should be avoided in areas where this is a potential hazard. Effects from competition will be realized; however, the use of this technology should be seen as a trade-off between greater competition realized with a bad weed infestation and lesser competition when complete weed-free conditions are employed. In cases where the latter condition is not realistic or is unobtainable, the living mulch system is recommended. Labor availability and cost is a major criteria in making the choice to use this sort of system. In lower rainfall areas, the competition for moisture may be too great and result in lower yields of coffee.

Intercropping with Food Legumes

This practice is recommended only in between the rows of young coffee. The practice is similar to that of living mulches and has similar benefits and disadvantages. Land preparation for the food legume intercrop can also serve as weeding for the coffee. In areas where the farmer has limited land or puts little emphasis on coffee management, this practice will help to concentrate the labor inputs. Competitive varieties of haricot bean planted in closely spaced rows or broadcast seeded are recommended. The close spacing should help to make the food crop more competitive.
so that little additional handweeding is needed between the rows. Chickpeas planted late in the season in areas where there is a definite dry season (Haraghe) and where there is sufficient residual moisture for both the coffee and the chickpeas, may also have the advantage of concentrating labor (combining land preparation and weeding). This practice should not be used if moisture is limiting. Other considerations for successful introduction of this practice should include: whether or not wild animals will be attracted to this crop creating more damage on coffee (Illubabor, Kefa, and parts of Wellega); the food crop preferences of the people; and labor availability. This practice is traditionally used in some areas, but has not received attention from researchers in order to improve it.

**Planting under Shade**

At this time, it is recommended to plant coffee under existing shade or to establish shade trees in new plantations. This is primarily for weed control purposes, because weeds, particularly perennial grasses and sedges, are less abundant in these conditions. Species that are recommended include: *Cordia abyssinica*, *Grevillea robusta*, *Albizia sp.* (several), and bananas. The leaf litter, particularly abundant under *Cordia* and *Grevilla*, can also provide a natural mulch and organic matter.

**Dead Mulch**

The use of dead mulch, particularly along the rows under the coffee canopy, does help to minimize handweeding and hoeing by preventing weed germination. Before the main rainy season, the mulch must be applied thick enough to prevent light from reaching the soil and maintained in order to have a positive effect. Apply the mulch near but not touching the base of the tree. To facilitate mulch availability, plant suitable species on contour strips, terrace edges, or on the field edges where competition with the crop in minimized. Species which can also be used as palatable forage and which do not spread by rhizomes are recommended. One-half hectare of Napier grass will produce enough mulch for one hectare of coffee (with the whole area mulched). Use green Napier grass without developed nodes, because if nodes are developed, it can re-root and become weedy. If fertilizer is being used, remove the mulch, fertilize and replace it. Weeds can also be used for mulch as long as they do not have seeds or are not the type which will regrow under wet conditions.

**Herbicides**

Translocated herbicides such as glyphosate (Roundup) are
# Guide to herbicides for use in coffee

<table>
<thead>
<tr>
<th>HERBICIDE, TRADE NAME &amp; FORMULATION</th>
<th>DOSE PRODUCT LITERS/HA</th>
<th>WEED STAGE</th>
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</tr>
</thead>
<tbody>
<tr>
<td># asulam</td>
<td>7.0-9.0</td>
<td>Post emergence to seedling</td>
<td>Many annual grasses and some perennial grasses.</td>
<td>Do not apply when rain expected within three hours. Can be mixed with atrazine (Candex) which kills many broadleaves. Do not use if intercropped. Use at 5-7 liters ha for 600 g/liter FW.</td>
</tr>
<tr>
<td>Asulox (400 g/l AqS)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*# dalapon</td>
<td>4.5-8.0 kg</td>
<td>Post emergence to actively growing perennial grasses when 15-30 cm tall.</td>
<td>Annual and perennial weeds.</td>
<td>A split application may be needed for perennial control 3 weeks apart. Symptoms may take 2-3 weeks to appear. Corrosive to iron.</td>
</tr>
<tr>
<td>Many brand names (740 g/kg SP)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*# fluazifop-methyl</td>
<td>2.0 (annuals)</td>
<td>Post emergence to actively growing perennial grasses. Poor control of Digitaria scalarum.</td>
<td>Annual and perennial weeds.</td>
<td>Can be used safely with legume intercrops at low rate. If weeds too large will not control.</td>
</tr>
<tr>
<td>Fusilade (125 g/liter EC)</td>
<td>6.0 (perennials)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>HERBICIDE, TRADE NAME &amp; FORMULATION</th>
<th>DOSE PRODUCT</th>
<th>WEED STAGE</th>
<th>WEEDS CONTROLLED</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>*# glyphosate Roundup (360 g/liter HL)</td>
<td>4.0 LITERS/HA</td>
<td>Post emergence to actively growing perennials with at least 4-5 leaves but not too old.</td>
<td>Both perennial and annual weeds and some sedges.</td>
<td>Use clean water only. Avoid contact with leaves, suckers, and green bark of coffee. Use low drift nozzles. Do not mix with other herbicides. Leaves no soil residues. Non-selective. Do not apply if rain expected within 8 hrs. May require split application, cultivate 10-14 days after first spray to encourage re-growth and spray again.</td>
</tr>
</tbody>
</table>
## Guide to herbicides for use in coffee

<table>
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<th>LITERS/HA</th>
<th>WEED STAGE</th>
<th>WEEDS CONTROLLED</th>
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</tr>
</thead>
<tbody>
<tr>
<td># paraquat Gramoxone (200 g/liter ML)</td>
<td>2.0</td>
<td>Post emergence to actively growing young weeds up to 30 cm tall. If the perennials will be weeds are taller, scorched but will regrow, reapply when weeds are smaller.</td>
<td>Many annual grass and broadleafed weeds. Leaves of</td>
<td>Use clean water only. Avoid contact with crop leaves, suckers, green bark. Use low drift nozzles. Can be applied frequently, economics permit. No residual activity and non-selective. EXTREMELY HAZARDOUS, USE ALL NECESSARY PRECAUTIONS.</td>
<td></td>
</tr>
</tbody>
</table>

* Recommended by Institute for Agricultural Research
# Recommended for use by other countries in the region.
recommended primarily for perennial grass and sedge control preferably before the establishment of the coffee. These weed species (*Digitaria abyssinica* and *Cynodon nlemfuensis*, commonly known collectively as couch grass) are difficult and labor intensive to remove. They will most likely be found in selective areas where there has been no previous cropping history, no intensive shade, or previously fallowed land. Under these conditions, chemical weed control is recommended because it is the most cost effective. If done carefully and completely, the initial investment cost should last for some time.

If intercropped with haricot beans, use alachlor (Lasso), fluazifop-methyl (Fusilade), linuron (Afalon), pendimethalin (Stomp) and refer to use recommendations for haricot beans. Do not use asulam + ioxynil (Actril DS) or asulam + atrazine (Candex 70) because these are damaging to the beans.

There are other herbicides available to control annual weeds in coffee; however, at this time herbicides are only being recommended for controlling the problematic perennial grasses because non-chemical methods can be economically employed by farmers, especially on small areas, for other types of weeds. As economic conditions change, this recommendation may be adjusted accordingly.

Refer to the table for herbicide recommendations.

**Cotton**

**Critical Weed-free Period**

Cotton is very susceptible to weed competition in its early growth stages because it is slow growing and a very poor early competitor. The actual period depends upon whether cotton is grown under rainfed or irrigated conditions. For irrigated cotton, the critical period is from early establishment to 60 days after planting. When no weeding is done there is a potential yield reduction of at least 73%.

Cotton is particularly susceptible to weed competition where there is low moisture and low fertility.

Late germinating weeds can interfere with harvesting and can contaminate the lint (*Bidens pilosa* is an example.) Weeds can also get in the way of insecticide sprays reducing their effectiveness.

**Land Preparation**

Establish a good seedbed free from weeds and crop residues. Start ploughing early enough so that planting is not
delayed. Plant as soon after ploughing as possible. Avoid too fine a seedbed because this may crust after rain or irrigation. Before planting and during the dry season, control perennial weeds, primarily sedges. See control measures in Chapter IV for these weeds. If perennial sedges are problematic, plough deeply, if possible to 40 cm.

Competitive Cropping and Good Husbandry

Refer to the Institute for Agricultural Research recommendations.

Number of Weedings

Cotton requires three to four weedings depending upon the conditions. This may or may not be economic. Determine this for each situation.

Handweeding and Hoeing

Traditionally, farmers usually wait too long before starting to weed this crop and yield reduction occurs. It is recommended to plant the crop in rows which will facilitate weeding. Use small, light-weight hoes or scuffles to remove small weeds faster. Start weeding 7-10 days after emergence, moving along the row. Leave areas between the rows for later. This will take less time and eliminate competition near the crop plants. At thinning, weed thoroughly. Repeat two more times. Cultivate to a shallow depth when weeds are small to avoid damaging the crop roots. Cultivation is also useful for breaking crusted soil to allow better water penetration.

Interrow Cultivation

Tractor- or animal-drawn cultivators can be efficiently used for interrow cultivation. This can greatly speed up the weeding operation and reduce labor requirements. For tractor-drawn implements, use sweeps which cultivate 2-5 cm deep. Use frequently during the early growth of cotton (once per week).

Noxious Weeds

As previously mentioned, perennial sedges are one of the most difficult to control weeds in irrigated cotton. Refer to Chapter IV for control recommendations.

Herbicides

For cotton grown on a medium scale, herbicides are very
# Guide to herbicides used in cotton

<table>
<thead>
<tr>
<th>HERBICIDES, TRADE NAME &amp; FORMULATION</th>
<th>DOSE PRODUCT LITERS/HA</th>
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</tr>
</thead>
<tbody>
<tr>
<td>*# diuron</td>
<td>0.5-1.5 kg</td>
<td>Pre-emergence</td>
<td>Pre-emergence or early post emergence</td>
<td>Many annual grass and broadleafed weeds.</td>
<td>Do not use on sandy soils. Do not use with insecticide seed treatment.</td>
</tr>
<tr>
<td>Karmex, Diamex</td>
<td>(800 g/kg WP)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*# fluazifop-butyl</td>
<td>2.0</td>
<td>Post emergence</td>
<td>Post emergence at 2-4 leaf stage</td>
<td>Many annual and perennial grasses.</td>
<td>Use higher rate for 6 liter for perennials. Slow acting. Do not mix with other herbicides.</td>
</tr>
<tr>
<td>Fusilade</td>
<td>(125 g/Liter EC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*# fluometuron</td>
<td>2.1 kg</td>
<td>Pre-emergence</td>
<td>Pre-emergence or early post emergence</td>
<td>Many annual broadleafed weeds and some grasses.</td>
<td>Do not use on sandy soil. Do not use with systemic insecticides. Apply to moist soil. May be mixed with metolachlor.</td>
</tr>
<tr>
<td>Cotoran</td>
<td>(800 g/kg WP)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># metolachlor</td>
<td>2.0</td>
<td>Pre-emergence</td>
<td>Pre-emergence</td>
<td>Many annual grasses and some broadleafed weeds.</td>
<td>Do not use on sandy soil. Incorporate mechanically or with irrigation under dry conditions into top 5 cm. May be sold in mixtures: fluometuron, prometryne.</td>
</tr>
<tr>
<td>Dual</td>
<td>(720 g/Liter EC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong># norflurazon</strong>&lt;br&gt;Zorial&lt;br&gt;(800 g/kg WP)</td>
<td>1.4-2.8 kg</td>
<td>Pre-emergence</td>
<td>Pre-emergence</td>
<td>Most annual weeds and suppresses nutsedges.</td>
<td>Long residual activity. Do not replant with another crop other than cotton.</td>
</tr>
<tr>
<td><strong># prometryne</strong>&lt;br&gt;Gesagard&lt;br&gt;(500 g/liter FW)</td>
<td>2.4-3.2</td>
<td>Pre-emergence</td>
<td>Pre-emergence or early post emergence</td>
<td>Annual broadleafed weeds and some grasses.</td>
<td>Do not use on sandy soil. Moist soil is required. Mixtures with Dual (Codal) also have good success.</td>
</tr>
<tr>
<td><strong># trifluralin</strong>&lt;br&gt;Treflan&lt;br&gt;(480 g/liter EC)</td>
<td>1.5-1.0</td>
<td>Pre-plant incorporated</td>
<td>Pre-emergence</td>
<td>Many annual grasses and some broad-leaved weeds.</td>
<td>Incorporate immediately into upper 5-10 cm. Use lower rate on sandy soils. Can be used with other herbicides: prometryn, fluometuron, norflurazon. Resistant to leaching.</td>
</tr>
</tbody>
</table>

* Recommended by Institute for Agricultural Research  
# Recommended for use in other countries in the region.
useful and often more economic than hoeing or handpulling. They can assist in maintaining a weed-free crop at early stages. Herbicides, giving early control, can be combined with later handweeding or hoeing.

Herbicides can be banded over the row and combined with handweeding or interrow cultivation. This may be a more economic method than broadcasting the herbicide.

Several of the recommended herbicides can be used directed post emergence: diuron, fluometuron, and prometryn. This method is more complicated to use unless the application is carefully done; therefore, although it is possible, it is not recommended.

As mentioned in the table, many of the herbicides are available in mixtures. This offers a wider control spectrum.

Under irrigation, there may be a problem of the herbicides persisting long enough. Trifluralin, although more difficult to use because it has to be mechanically incorporated, is recommended for this condition. Its spectrum can be expanded by mixing it with other herbicides.

Prevention

Sow seed which is weedfree. Keep weeds from seeding after the critical period has passed. Remove all weed residue from the field after harvest to avoid seeding.

HOT PEPPER AND TOMATO

Critical Weed-free Period

Hot peppers are most sensitive to competition from early establishment to flowering. Direct-sown peppers are more susceptible to weed competition than transplants. If transplanted, the first 4 weeks after transplanting are critical. Peppers compete poorly with weeds. Yield loss figures range from 85%-100% if left unweeded. A moderate infestation will reduce yields by 30%.

Tomato is similar to pepper in that it is most sensitive to competition in the early growth stages. The competitiveness of the crop depends on whether it is direct seeded or transplanted as well as on the variety, plant population, spacing used, climatic conditions (temperature and rainfall), weed species and numbers of weeds present affect competition. If tomato transplants are kept weedfree for the first 30-40 days and if they make substantial growth, they should be able to withstand further competition. Direct sown
tomatoes are less competitive. Yield losses have been reported to be 70% if there was no weeding.

Land Preparation

Plant seeds or transplants into a well-prepared seedbed to minimize competition with weeds. Remove any perennial weeds prior to planting. Have planting precede land preparation as soon as possible to give the crop the competitive advantage.

Competitive Cropping and Good Husbandry

Healthy transplants are the preferred method of planting because they are more competitive with weeds. Transplants should be grown in weed-free conditions so that weeds or their propagules are not being transplanted from one area to another. When seeding transplants, seed thickly and then thin to about 8 cm square per plant when the first true leaf appears. This will encourage good root development and minimize shock when transplanting because there will be less disturbance of the root system. If possible, transplant when conditions are moist and cool. Use a fertilizer starter solution which is high in phosphorous at planting. Control insect pests and diseases.

For tomatoes, do not allow fruit set to occur before there has been good root development. If flowers have started forming before the tomatoes are well established, remove them. Staking tall tomato varieties to keep them off the ground has several advantages: increase in marketable fruit, easier to weed, easier to harvest, cleaner fruit, and potentially less disease. Pruning to a single stem can help increase yields over time. Staking and pruning are most economic for long-season varieties.

Number of Weedings

Three weedings are recommended. One soon after emergence or transplanting, within the first 3-4 weeks, and the second and third as needed.

Handweeding and Hoeing

Row planting is recommended in order to facilitate weed removal. Be careful when hoeing to avoid damaging the stem of the plant because diseases can enter a wound. Hoe or handpull when the weeds are small.

Mulching

Since this is a relatively high value crop, it will be
Guide to herbicides for pepper

<table>
<thead>
<tr>
<th>HERBICIDE TRADE NAME &amp; FORMULATION</th>
<th>DOSE PRODUCT</th>
<th>CROP STAGE</th>
<th>WEED STAGE</th>
<th>WEEDS CONTROLLED</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td># chlorpropham</td>
<td>5-15</td>
<td>Pre-emergence</td>
<td>Annual weeds.</td>
<td>Do not use on sandy soil.</td>
<td></td>
</tr>
<tr>
<td>Many brands (480 g/liter EC)</td>
<td></td>
<td>or early post emergence to seedlings less than 1 cm tall</td>
<td>Moisture is necessary for the chemical to work.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DCPA Dacthal (750 g/kg WP)</td>
<td>7-16 kg</td>
<td>Post emergence</td>
<td>Many annual grasses and some broadleafed weeds.</td>
<td>Effectiveness may be lost if soil is disturbed.</td>
<td></td>
</tr>
<tr>
<td># chlorothal-dimethyl</td>
<td>5.6-8.4</td>
<td>At seeding or transplanting</td>
<td>Annual grasses and many broadleafed weeds.</td>
<td>Use low rates on sandy soils. Can be banded over the row.</td>
<td></td>
</tr>
<tr>
<td>Dymid (800 g/liter EC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

Note: Other herbicides are safe to use on pepper but require pre-plant incorporation. This method of application is too difficult with presently available equipment. These herbicides are: bensulide, naproanide, pendimethalin, trifluralin.
## Guide to herbicides used for tomato

<table>
<thead>
<tr>
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<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td># chlorothal-dimethyl</td>
<td>AS FOR PEPPER</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># diclofop-methyl Illoxan (360 g/liter EC)</td>
<td>6.0 Pre-plant or pre-transplant</td>
<td>Post emergence at 1-4 leaf stage when actively growing</td>
<td>Annual grasses.</td>
<td>Soil moisture is needed.</td>
<td></td>
</tr>
<tr>
<td># diphenamid</td>
<td>AS FOR PEPPER</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># metobromuron Patoran (500 g/kg UP)</td>
<td>3-5 kg 4-5 days before transplanting</td>
<td>Pre-emergence</td>
<td>Many broadleafed weeds and some annual grasses.</td>
<td>Apply to moist soil. Do not use on sandy soils. Can be applied with metolachlor as Galex (250 + 250 g/liter) 5-6 liter product/ha.</td>
<td></td>
</tr>
<tr>
<td># metolachlor Dual (720 g/liter EC)</td>
<td>2.0-3.0 Pre-transplanting</td>
<td>Pre-emergence</td>
<td>Many annual grasses may occur if too much moisture needed. Injury and broadleafed weeds, C. esculentus rain or irrigation may be controlled.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Recommended by Institute for Agricultural Research

# Recommended for use in other countries in the region.
economic in many situations to mulch the crop rows with dead plant material. Make the mulch thick enough so that light can not penetrate, and maintain at this level. Mulch will also help to keep the fruit clean and prevent disease spreading from splashed soil.

Herbicides

Generally, herbicides are not recommended if the area planted is small; however, if labor for weeding is limited, it may be economic to apply herbicides on a limited basis. This practice has not yet been tested extensively under Ethiopian conditions. Recommendations should be tested before using them extensively.

POTATO

Critical Weed-free Period

Weed competition is most damaging to potatoes in the early growth stages, until canopy formation; therefore, thorough weed control is necessary from emergence to 7-12 weeks, depending upon the variety and growth conditions.

Land Preparation

Produce a weed-free seedbed. Eliminate perennial grasses and sedges as much as possible before planting. Potatoes are usually grown on ridges which can be formed before or after planting. Ridges are usually formed before planting when herbicides are used.

Competitive Cropping and Good Husbandry

Handle seed potatoes carefully to avoid bruising or injury. Plant them when they are fresh (turgid) and before extensive water loss causes deterioration. Try to avoid cutting the seed potatoes because, unless treated with a pesticide, pests may be introduced. Plant soon after land preparation to avoid early germinating weeds, and minimize competition. Potatoes pre-sprouted under diffuse light will speed up emergence time and decrease the time between planting and emergence.

Plant using optimum population and row spacing recommended for the particular variety being grown. The ridges should be spaced so that cultivation can be accomplished but also so that fast canopy cover occurs. Use a good routine for insect and disease pest treatment. Ridge or re-ridge potatoes when cultivating for weed control. Ridges prevent greening, insect pest infestation, and makes harvesting much easier.
Number of Weedings

Generally, a minimum of two to three weedings are necessary, depending upon the competitiveness of the variety, the number and type of weeds, and the growing conditions. A less competitive variety may need more weedings before canopy closure.

Handpulling and Hoeing

Handpulling is very tedious and is only recommended for roguing tall vigorous weeds emerging late in the season which have escaped other control methods.

If weed control is done using hoeing, use shallow cultivation because the potato roots are easily damaged. Use a scraping action to eliminate weeds and to build up the ridge. Weeding should begin early to eliminate weeds before they are more than 10 cm high. If weeding is delayed, it is more difficult to use shallow cultivation; therefore, potato roots are damaged and yield is reduced. The use of small, light-weight hoes rather than heavy hoes which require a chopping action is recommended to ensure shallow cultivation.

Mechanical Cultivation

Animal or tractor cultivation can be used for weeding and ridging simultaneously. This should be carefully done to avoid damaging the potatoes. Cultivation or ridging may reduce herbicide performance if carried out after a soil-acting herbicide is used (alachlor, EPTC, linuron, metolachlor).

Herbicides

Herbicides are recommended for use in larger potato production areas where there are labor shortages.

It is recommended:

- to ridge at planting and use herbicide for all subsequent weed control;

- or use a small ridge at planting, apply post-emergence herbicide for early season control, and do a second ridging operation;

- or flat plant, ridge (controlling weeds also), and apply a post-emergence herbicide (metribuzin) for later season control.
Choose one of these three methods depending upon weed species and weed control needed.

REFERENCES

The following references were used in writing Chapter III and are found in Annex 8: 1, 9, 14-21, 23, 25, 26, 27, 42, 44, 46, 47.
### Guide to herbicides used for potato

<table>
<thead>
<tr>
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<th>CROP STAGE/WEED STAGE</th>
<th>WEEDS CONTROLLED</th>
<th>REMARKS</th>
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</thead>
<tbody>
<tr>
<td># alachlor Lasso (480 g/liter EC)</td>
<td>2.0-6.0</td>
<td>At planting and pre-emergence</td>
<td>Pre-emergence</td>
<td>Annual grasses and some annual broad-leaved weeds. Do not use on sandy soils. Use in herbicide mixtures for better weed control. Needs moisture.</td>
</tr>
<tr>
<td># chlorbromuron Maloran (500 g/Kg WP)</td>
<td>2.0-6.0 kg</td>
<td>Pre-emergence</td>
<td>Pre-emergence or early post emergence</td>
<td>Annual broadleafed weeds and some grasses. Do not plant any crops besides potato, wheat, or soybean for 6 months after application. Do not use on low organic matter soils. Needs moisture.</td>
</tr>
<tr>
<td># dalapon Many brand names (740 g/Kg WP)</td>
<td>4-13 kg</td>
<td>Pre-emergence or pre-plant</td>
<td>Post emergence. Apply to growing foliage, wait 3 days before cultivation, if any</td>
<td>Annual and perennial grasses. May affect color of red potatoes. A split application on perennials may give better control.</td>
</tr>
<tr>
<td># diclofop-methyl Illoxan (360 g/liter EC)</td>
<td>2.0-3.0</td>
<td>Pre-emergence and early post emergence</td>
<td>Post emergence 1-4 leaf stage</td>
<td>Annual grasses. Including wild oats. Needs moisture. Weeds should be actively growing.</td>
</tr>
</tbody>
</table>
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<tbody>
<tr>
<td># EPTC Eptam (720 g/liter EC)</td>
<td>2.0-4.0</td>
<td>Pre-plant incorporated</td>
<td>Pre-emergence</td>
<td>Grasses and some broadleafed weeds. Controls sedges.</td>
<td>Apply to dry soil, incorporate immediately. Lasts 4-6 weeks in warm conditions.</td>
</tr>
<tr>
<td># fluazifop-butyl Fulsilade (125 g/liter EC)</td>
<td>2.0</td>
<td>Post emergence before canopy closes</td>
<td>Post emergence at 2-4 leaf stage</td>
<td>Annual and perennial grasses.</td>
<td>Avoid drift. Do not mix with other herbicides. Use 6 liters for perennial weed control.</td>
</tr>
<tr>
<td># Linuron Afalon (500 g/kg WP)</td>
<td>2.0-4.0 Kg</td>
<td>Pre-emergence</td>
<td>Pre-emergence and early post emergence</td>
<td>Many annual grasses and broadleafed weeds.</td>
<td>Do not use on sandy soils.</td>
</tr>
<tr>
<td># metobromuron Patoran (500 g/kg WP)</td>
<td>3.0-6.0 Kg</td>
<td>Pre-emergence at planting or just after hilling</td>
<td>Pre-emergence</td>
<td>Many annual grasses and broadleafed weeds.</td>
<td>Apply in mixtures to increase spectrum.</td>
</tr>
</tbody>
</table>

Apply to moist soil.
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</thead>
<tbody>
<tr>
<td># metolachlor Dual (720 g/liter EC)</td>
<td>1.4-4.0</td>
<td>Pre-emergence</td>
<td>Pre-emergence</td>
<td>Many annual grasses. Some control of C. esculentus.</td>
<td>Usually applied in mixtures: Galex (+ metobromuron). Incorporate lightly if dry.</td>
</tr>
<tr>
<td># metribuzin Sencor (700 g/Kg WP)</td>
<td>0.3-1.0 Kg</td>
<td>Pre-emergence or early post emergence</td>
<td>Pre-emergence and early post emergence up to 4 cm tall</td>
<td>Many annual grasses and broadleafed weeds.</td>
<td>Apply to moist soil. Do not use on sandy soils. Do not incorporate mechanically. Do not apply early post to red skinned varieties.</td>
</tr>
<tr>
<td># pendimethalin Stomp (500 g/liter EC)</td>
<td>2.0-4.0</td>
<td>Pre-emergence</td>
<td>Pre-emergence</td>
<td>Annual grasses and some broadleafed weeds</td>
<td>Apply before crop emergence but after ridging.</td>
</tr>
<tr>
<td># prometryne Gesagard (500 g/liter FW)</td>
<td>2.0-4.0</td>
<td>Pre-emergence or early post to seedling weeds.</td>
<td>Many annual broadleafed and some grass weeds.</td>
<td>Apply to moist soil. Use lower rate on sandy soils.</td>
<td></td>
</tr>
</tbody>
</table>
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<table>
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</tr>
</thead>
<tbody>
<tr>
<td># terbutryn Igran (500 g/liter EC)</td>
<td>1.6-5.0 LITERS/HA</td>
<td>Pre-emergence</td>
<td>Pre-emergence or early post emergence, less than 8 cm tall</td>
<td>Many annual broad-leaved weeds and grasses.</td>
<td>Apply to moist soil. Apply in mixture with terbutylazine (Topogard) Do not use on sandy soils.</td>
</tr>
</tbody>
</table>

* Recommended by the Institute for Agricultural Research
# Recommended for use in other countries in the region.
Chapter IV

Specific Weed Problems and Their Control
Parasitic Weeds

STRIGA HERMONTICA AND STRIGA ASIATICA

General Information

Striga occurs in the Scrophulariaceae family. It is known by many local names in Ethiopia: 'Deisso', 'Hunegaise', 'Atkur', 'Akentchera', 'Yemender kitegne', 'Tesho's weed' and others. The common name used for this weed in other parts of the world is 'witchweed'.

Striga attaches itself to the crop host plant's roots and in doing so, weakens the crop plant by robbing nutrients, hindering fertilizer uptake, and making it more susceptible to drought. Farmers may tell you that Striga is drying the plant out because the crop plant looks stunted, with yellowish and brown, wilted or dried leaves.

Striga attacks from underground and damages the plant before the weed can be seen above ground. Precise yield reduction figures are difficult to make; however, complete crop failure can occur causing farmers to abandon their fields. Most farmers having Striga for some time in their fields realize that the problem is serious. Recognition of the seriousness of the problem by people who have not seen the problem first hand is limited. Education of these people is needed. Both control practices and prevention are essential.

Distribution and Occurrence

The two species that are found in Haraghe Region are Striga hermonthica, which has pink flowers and is relatively tall (0.5 m) and Striga asiatica which has bright red or orange flowers and is relatively short (0.2 m). In parts of Eritrea, Tigrai, Welo, Gojam, Northern Shoa and Gondar, only Striga hermonthica is found. In Gama Gofa and Sidamo, only Striga asiatica is found. Both species are parasites on sorghum, maize and finger millet. Another species can be found on sugarcane and although sited in Ethiopia, it does not appear to be very important. Striga has also been seen in teff fields in Welo and Northern Shoa. Striga can also occur on some wild host plants such as Dinebra retroflexa, Sorghum sp., Rottboellia cochinchinensis, and others.

Striga is favored by low fertility and unreliable rainfall. It therefore often occurs in areas where peasant farmers are less productive and have fewer resources for control options, little cash for buying inputs, or are farming a small amount of land which makes crop rotation difficult. The infestations also tend to occur in areas which have
increasing population pressures, a decrease in animal population and therefore manure resource, and soil fertility/conservation problems.

Life Cycle and Growth Characteristics

1. Seeds

*Striga* seeds are produced in enormous numbers. Each seed capsule produces 400-500 seeds, so that a single plant can produce over 20,000 seeds. The seeds are very small and dark and resemble dust. Some farmers do not realize that the plant reproduces by seed because the small seeds are unrecognizable to them. The seeds are dispersed by wind, water, in manure, and in soil carried on tools, shoes, and hooves. The seeds can remain viable up to 20 years in the soil. Because there are a large number of seeds and they have a long life in the soil, it is very difficult to totally eliminate *Striga* once it has become established. It takes a long-term commitment to reduce the infestation to low levels.

2. Germination and attachment to the host

The seeds only germinate when stimulated by natural chemicals exuded from the roots of the host plant. The *Striga* seeds have to be very close to the crop's roots to be stimulated to germinate. Germination usually takes place after the rains begin and the host plant has had some time to start growing. Where rainfall is erratic in the early part of the season, earlier sown crops may be more affected, whereas crops sown when the rain is continuous may be unaffected until late in the season. Soil temperatures for germination need to be close to 30 degrees C. After germination, *Striga* attaches itself to the root of the host and starts to remove nutrients and water from the host. It also causes a physiological change in the host by encouraging root growth but stunting shoot growth. Most of the damage is done at this stage, before *Striga* emerges from the soil.

3. Growth and flowering

*Striga* takes 2-3 weeks to emerge after it has attached to the host roots. Some *Striga* remains subterranean (underground). After emergence it takes about 4-10 weeks to complete its life cycle depending upon the environmental conditions. *Striga* can complete its life cycle on a host which has been harvested but the roots remain. *Striga hermonthica* is cross pollinated by various insects. This accounts for the wide variation in this species.
Symptoms

The symptoms on the crop plant look similar to a disease. There can be stunting of the host plant and failure of the panicle to form in severe infestations. *Striga asiatica* can cause the plant to appear wilted with leaf rolling even though there may be plenty of moisture. *Striga hermonthica* can cause chlorotic lesions or yellowish spots on the leaves. Often there are more symptoms on low fertility soils and under drought conditions.

Control Recommendations

*Striga* is very difficult to control. Prevention is best followed to minimize the spread. No single control measure will get rid of *Striga*. An integrated, long-term approach must be adopted. Farmers must be convinced of the severity of the problem and taught that in order to control *Striga* they may have to work several years before seeing the full result of their labors.

The following recommendations are made according to the infestation severity. These recommendations can be done more or less easily by farmers without too much in the way of additional resources. The other practices listed have also proven to be effective but require more flexibility in the farmer's time and resources, or an input such as a resistant variety which is not presently available. A careful farming systems analysis must be made in order to choose a suitable control program if diverting from Recommendations 1-4 below.

1. **Severe infestation**

Fallowing or crop rotation is recommended. Take the area out of sorghum and/or maize production completely. Under very severe infestation the farmer will not be able to adequately control the *Striga* and substantial yield reduction will occur. It will also be very difficult to stop further *Striga* seed production. Rotate with any crop (other than sorghum, maize, or finger millet) that the farmer feels to be a suitable choice. If there is no possibility of rotation because the land area is too small, discuss a new land allocation for the farmer with the village authorities so that he can produce a suitable amount of food and so that the severely infested area can be fallowed or planted to a non-susceptible crop.

2. **Moderate infestation**

Follow both fertilizer and manure application, handpulling, and planting time recommendations as follows:
It is recommended that the farmer apply manure or fertilizer to the infested areas to increase the fertility. Apply the manure or fertilizer to the whole field if it is possible. If fertilizer is used, combine a nitrogen topdress with an early weeding. A second topdressing of fertilizer can be used just before crop flowering, particularly where Striga patches are more serious. Nitrogen supplied by these two sources should help to lessen Striga attack, particularly early in the season. This practice must be accompanied by handpulling of the Striga, because later in the season Striga germination may be encouraged by the more extended root system of the host plant (sorghum or maize) due to fertilizer response.

Early handpulling or hoeing, that is after Striga emergence but before flowering, will cause the Striga to resprout. This is because the shoot breaks off at the base which causes basal buds to sprout. This may result in more shoots. It is very important to continue pulling after flowering but before seed shed to ensure that the Striga does not seed in the field. This practice may be too laborious for the farmer depending on his labor supply and other crop production activities. If this is the case, follow the next recommendation of pulling or hoeing only after flowering. In summary, if early pulling is encouraged, pulling must continue to remove all shoots once per month after flowering but before seed shed. Early pulling may decrease the potential yield reduction somewhat.

Pulling or hoeing after flowering but before seeding with no early pulling will reduce the amount of seed but not prevent yield reduction. Pull once per month after Striga flowers continuing through and beyond harvest. This practice may need to continue for several years before the infestation is substantially reduced.

After pulling the flowering Striga plants remove them from the field and burn or bury them immediately. Avoid grazing the infested area until after the Striga is removed.

Row planting can help to speed up handpulling by organizing the labor to go along the rows. Also this facilitates interrow cultivation using hoes or animal-drawn equipment doing less damage to the crop compared to when it is broadcast seeded. Use the recommended seeding rate for a row-seeded crop. However, if farmers use thinnings to feed their livestock during the season, add 25% to the recommended rate for a row-planted crop.
There is rarely much choice for planting time; however, by choosing short-season cultivars and using a planting strategy, infestation by Striga may be avoided or reduced by: (1) planting late when rains become more continuous thus avoiding intermittent dry spells (of 1-2 weeks) which favor Striga germination, or (2) by planting a trap crop early followed by a short-season variety later.

This method needs to be tested for feasibility in various areas prior to recommendation.

3. Light infestation

Pull Striga at flowering but before seed shedding as 2 above, through and beyond harvest. Avoid grazing until after Striga is removed. Destroy the pulled Striga as in 2 above.

Maintain soil fertility as stated above in 2.

Prevention

1. Maintain soil fertility.

2. Clean implements (plows, hoes) before moving to a new field. Avoid any transfer of soil from an infested area to a non-infested area.

3. Avoid grazing animals in the infested areas at least until the Striga has been removed.

4. Destroy all pulled Striga plants by burning or burying immediately.

Other Control Measures

1. Crop rotation and trap and catch crops

Rotate the susceptible host crops with other crops, such as haricot beans, sweet potatoes, noug, and teff, among others, which will not be affected by Striga. Trap crops are crops which stimulate Striga to germinate but are not parasitized. These 'false hosts' include cotton, linseed, field peas, sunflower, groundnut, cowpeas, and soybeans, among others. These crops are beneficial in reducing the Striga seed reservoir. Legumes can also have beneficial effects by adding nitrogen to the soil. If the Striga infestation is severe, this method will take many years to be successful.

If the growing season is long enough, it may be feasible to plant an early catch crop (a crop which is attacked by Striga) harvesting it prior to planting the susceptible
crop. To be successful, the temperature and moisture regimes must be favorable to encourage *Striga* germination when the catch crop is present.

Unfortunately, farmers often do not have the flexibility or enough land to practice rotation with crops other than their major staple food crop. There may not be a market or need for the alternative crops. The farming system and farmer's attitudes towards this method need to be analyzed to determine if this is possible.

2. Variety resistance

Breeding cultivars which are resistant or tolerant (less damaged) is the most practical control measure. This work is in the research phase in Ethiopia so that the seeds are not yet available. In the future, some promising varieties should be made available.

3. Herbicides

No herbicide can provide complete selective control of *Striga*. A 0.1% solution of 2,4-D can be applied to emerged *Striga* plants in cereals as a contact post-emergence spray. This requires row planting in order to keep track of which area has been sprayed. A spot treatment approach can be used, that is only spraying the *Striga* plants where they appear. This treatment can be applied monthly.

Herbicides may not be readily available or be too costly. This control method is still under test for Ethiopian conditions to find out how well it will work and how economic it will be.

4. Biological control

There are some potential biological control organisms which have not yet been fully researched. One example, is a gall forming weevil (*Smicronyx umbrinus*) which occurs in small numbers in Ethiopia, and lays its eggs in the flower buds of the *Striga*. The grubs feed on the undeveloped seeds and reduce seed production. Presently these insects do not occur in large enough numbers in nature to do any real harm to *Striga* in most situations.

5. Seeding rate

*Striga* tends to be suppressed by shade, so where fertility and rainfall permit, increased planting density should be beneficial.
Orobanche species in the family of Orobanchaceae, commonly called broomrape, are root parasites that attack broadleafed plants, particularly in the Leguminoseae and Solanaceae families. It is locally known in Ethiopia by 'yemeder kitegne', 'delantuba', 'yetoba kula', 'sete yegeb eras'.

Orobanche, an obligate total parasite having no photosynthesis of its own, attaches itself to the roots of the host and utilizes water, minerals, and carbohydrates from the host plant, causing drought stress and wilting of the host. This parasite damages the crop before the parasite emerges.

Distribution and Occurrence

There are about 140 species of Orobanche which attack both cultivated and wild species. There are three major species present in Ethiopia, each having some specificity as to which crop it is more likely to attack: O. minor parasitizes many Compositae (safflower, noug, sunflower, lettuce), tobacco, groundnuts, and other legumes such as faba bean. O. cernua is on tobacco, tomato, eggplant; O. ramosa is also on Solanaceous crops (tomato, potato), linseed, rapeseed, and cabbage. Orobanche has a very wide environmental range, appearing in areas wherever the hosts grow. In Ethiopia it is particularly prevalent in the higher and middle elevation areas throughout the country.

Wild hosts that have been reported are: Galinsoga parviflora and Solanum nigrum for O. ramosa, and Datura stamonium, Bidens biternata, Tagetes minuta, and Xanthium sp. for O. minor.

Description

O. cernua can grow to be 10-50 cm tall, is usually unbranched but can be branched usually below ground. It has flowers up to 1 cm across which have a purple rimmed corolla, single bracts, and no bracteoles.

O. ramosa is distinguished by being branched, and grows to be 20-30 cm tall with a whitish stem. It has uniform, pale to bright blue flowers up to 2 cm long and 1 cm across which are more campanulate than the other two species (the mouth is wider than the tube). The flowers have a bract and two bracteoles.
O. minor grows 10-100 cm tall with single stems. The crinkly flowers are purplish, with streaky veins of purple. This is the most common in Ethiopia.

Life Cycle and Growth Characteristics

1. Seeds

Orobanche seeds are very small (0.25 mm long) and are produced in large amounts: 60,000-94,000 per stem. They must undergo a period of dormancy before germination. They can last in the soil up to 20 years.

2. Germination and attachment

A chemical stimulant which is secreted from the host causes the seeds to germinate up to 1 cm from the host root; however, seeds have to be within 2-3 mm of the root to become attached. Attachment must occur within a few days of germination. Secondary attachment points can develop to connect Orobanche rootlets with the host roots. Temperatures of 20-25 degrees C, favor germination. High pH (alkaline) conditions have been shown to inactivate the germination stimulant. Germination does vary with soil type, but generally Orobanche is more problematic on low fertility soils.

3. Growth and flowering

Once the Orobanche becomes attached to the host, a mass of tissue (nodule) develops up to 1 cm in diameter before a shoot forms. The shoot emerges rapidly and forms flowers within a few days after emergence. Seeds are produced in capsules which split in two parts when ripe.

Dissemination

Dissemination is mainly by mechanical means: by water, by wind aided through vibration of the stiff stem after it dries, and through movement by man.

Symptoms

Dramatic symptoms are not always apparent; however, sometimes in severe cases wilting or complete drying of the crop can be seen. Yield reduction occurs regardless of whether symptoms are readily noticeable. Four shoots of O. cernua per sunflower were reported to reduce yields by 20%. Other reductions are reported up to 34%. A single emerged Orobanche can reduce faba bean yield by 8% and a greater infestation can cause total crop loss. In general, yield
reductions are related to the number of parasitic stems per plant.

Control Recommendations

So far there is no consistent, economical method for controlling Orobanche. An integrated program combining the following measures can reduce infestations, but usually will not eradicate Orobanche.

1. Prevention and avoidance

Remove adult plants before flowering and seed production occur. It is difficult to clean these weed seeds from crop seed because they are so tiny.

2. Mechanical

Handpulling can greatly reduce seed production and eventually greatly reduce the infestation. In other parts of the world, weekly handpulling has reduced infestations by 85% in 2 years and 96% after 4 years. This method works well on small areas but is difficult on larger areas due to labor requirements. After pulling, the plants should be removed from the field and burnt or buried. Pull before flower development.

3. Rotation and trap crops

Rotation with crops which are not susceptible is a way to avoid the problem; however, unless rotation with non-susceptible plants is practiced for a long time, the problem will remain because of the long dormancy period of Orobanche seed.

Trap crops are those that stimulate Orobanche to germinate but are not parasitized by it. Use of these crops can help to deplete the Orobanche seed supply. Experimentation has shown the following crops to be effective: pepper (Capsicum annuum L.), cowpea (Vigna unguiculata [L.] Walp.), hemp (Hibiscus cannabinus L.), chicory (Chichorum intybus L.), horsegram (Polichos uniflorus Lam.), linseed (Linum usitatissium L.), noug, eggplant, haricot bean, sorghum, lucerne (alfalfa), soybean and chickpea. Wherever there is flexibility for rotation with these or any other non-susceptible crops, rotation should be considered.

5. Fertility management

Orobanche has been reported to be less serious under more fertile conditions. There has been evidence reported of
success in the few situations where increasing fertilizer rates has been tried. It is questionable as to how economic this method of reducing infestation might be. Further research for Ethiopian conditions is needed.

6. Flooding

Recent work suggests that where irrigation is possible O. cernua can be greatly reduced by 2 months of flooding. However, the implications of this treatment for crop diseases and soil salinity require further study. Economics must also be considered.

7. Resistant varieties

Sunflower varieties resistant to Orobanche are available in other countries but have not been widely tested in Ethiopia. There are differences in tolerances of local varieties of noug to this parasite; however, research information is limited at this time. This means of control is promising in the future. Host plant resistance may be specific to Orobanche species.

8. Herbicides

Although herbicides have been shown to be partially successful in controlling Orobanche in some crops, herbicides are not recommended at this time to small farmers because they are either not economic, not available, or difficult and dangerous to use. Allyl alcohol sprayed at a 0.1% solution on emerged but not flowering Orobanche shoots has proven to be quite successful in tomato; however, this material is very difficult to find. A low dose of glyphosate has been effective in faba beans when applied overall two to three times, and may be applicable to a few other crops including tobacco. Fumigants such as methyl bromide are also successful but very expensive and poisonous. Experiments with other herbicides have been conducted on a limited basis. Generally, use of chemicals will be restricted to large-scale commercial farms in the near future.

9. Biological control

A small fly, Phytomyza orobanchiae Kalt. has been used successfully in USSR and Eastern Europe. This fly occurs widely in Ethiopia but research is needed to see if it might be encouraged and exploited under local conditions. Where insecticides are used to control other pests, the fly is unlikely to be effective. The fly damages the plant by entering through the seed capsule and boring through the stem.
CUSCUTA

General Information

Cuscuta is not widespread in Ethiopia but it can be a serious pest where it occurs. Dodder is its common name and it is referred to as 'yenoug anbesa' locally. Unlike Striga and Orobanche, dodder is a stem parasite rather than a root parasite. Cuscuta, as a total parasite, reduces crop yields as well as acts as a contaminant in the host seed (Cuscuta seed in noug), which makes the seed unsaleable or of reduced value as an export crop. A single seed of Cuscuta can generate a plant which can be up to 5 meters in diameter affecting all hosts in this area. There has been one report of livestock being poisoned by hay which was 50% C. campestris.

Occurrence and Description

Although there are five or six species, only two are important in Ethiopia. Cuscuta campestris is the main species occurring in Ethiopia. C. epilinum also occurs. It is particularly severe in noug. Crops which are affected in Ethiopia include: noug, linseed, tomato, flowers, maize, soybean, and citrus. Grasses are rarely attacked. The age of the host may sometimes be critical, for example, older plants of tomato seem to be resistant.

C. campestris has stems which are 1-2 mm and bright orange to yellow, and is found worldwide on a wide range of hosts: herbaceous crops, flowers, and weeds. In Ethiopia, it occurs primarily on noug. Its flowers are 2-3 mm with corolla lobes with incurved tips and are found in clusters. Seed capsules are round, with two styles with knobs on the top, and do not split in half.

C. epilinum has larger flowers (3.0-3.5 mm) in dense clusters 5-10 mm across, a stem with few branches, and occurs mainly on linseed. The fruits have two styles which do not have knobs on the top. Identification of species is difficult but Cuscuta is generally easily recognizable because it looks like a yellow to orange string around the canopy of the host and is attached to the stem. The Cuscuta seeds are generally 1.0-1.5 mm.

Biology and Growth

Cuscuta can germinate spontaneously without any stimulant from the host. Germination can occur within the top 5 cm of the soil. A proportion of the seeds have a hard seed coat and must receive scarification before they will germinate.
This results in a prolonged pattern of germination over a period of years and reduces the risk of too many seeds germinating in the absence of a suitable host. Most seeds will have germinated after a 6-year period. After germination, the shoot grows out as a slender yellow stem which grows in a circle about once per hour in order to strike any object within a radius of 3-5 cm. Once it hits an object, it starts to twine around it. If it is a suitable host, haustoria will begin to develop within a few days on the inner face of the coil and penetrate the host tissue, then soil contact in host. If no host is contacted, the seedling loses its ability to parasitize and will die in about 7 days.

Once attached, dodder grows very rapidly and can attach at many places on the host stem. The haustoria or specialized tissue where the attachment takes place are the points where the parasite gets nutrients, water, and carbohydrates from the host. The parasite acts as a powerful sink or attraction of these elements from the host. Cuscuta can prevent the host from flowering and setting fruit. Severe infestations can cause complete crop failure.

Control Measures

1. Prevention

The use of clean seed is one of the most important measures farmers can use to prevent spreading in areas where it does not already occur.

2. Cultural methods

Planting crops in rows can facilitate dodder removal and limit its spread. It has been demonstrated that broadcast-seeded crops are usually attacked to a greater extent.

Crop rotation with crops which are not attacked by Cuscuta can help to contain the problem. Alternative hosts should be controlled.

3. Handweeding

Handpulling removes the problem to some extent, however any fragment of the parasite left on the host can regenerate. It is therefore difficult to remove unless the host plant is removed as well.

4. Resistant varieties

There are no known resistant varieties.
5. Herbicides

This method is not recommended at this time for small farmers. Although there are herbicides which show some promise in some crops, they have not been tested in Ethiopia. Most herbicides do not have enough residual activity in the soil to persist.

6. Biological control

Smicronyx jungerrmanniae Reich., a gall forming weevil, has been used successfully on C. campestris in Hungary and USSR. There is also a fungus, Colletotrichum gloeosporoides, in China. These have not yet been investigated for Ethiopia.
Perennial Grasses

This group of weeds includes such species as Digitaria abyssinica (scalarum) ('bora', 'ura', 'wariote'); Cynodon dactylon and C. nlemfuensis ('sardo', 'katisa'), collectively referred to as 'couch' (the Cynodon spp. are sometimes referred to as 'star grass'); Andropogon abyssinicus; Pennisetum clandestinum called Kikuyu grass; and others.

These weeds are noxious because they are very time consuming and difficult to remove. Perennial grasses are encouraged and flourish particularly in the highlands areas where cropped fields are left fallow during some seasons and where rainfall is prevalent. They can also be severe problems in perennial crops such as coffee.

They are one of the major reasons why farmers have to plough their land so many times. The maresha plough, by only stirring rather than turning the soil, encourages the propagation of these weeds unless ploughing is accompanied by manual removal of the rhizomes. Once the crop is seeded and growing, these weeds are very difficult to remove without destructive disturbance to the crop. There is evidence that Digitaria abyssinica may reduce yields of coffee not only through competition but also by allelopathy.

Biology

Perennial grasses are vegetatively propagated by underground rhizomes and/or above-ground stolons which happens by spread from growing plants or from rhizome or stolon pieces which have become detached from the main plant. As long as the piece contains a live node, it can start to grow. Nodes, or growing point areas, are located along these creeping stems and can form roots, shoots, and new rhizomes or stolons.

The nodes can remain inactive due to enforced apical dominance by other active nodes, or because of dormancy caused by unfavorable growing conditions. Dormancy can be broken by soil disturbance, cutting, or fragmenting of the rhizomes or stolons, thus breaking apical dominance, or by suitable climatic conditions. These grasses can also reproduce by seed. The major control methods relate primarily to killing the vegetatively reproducing parts: the rhizomes or stolons.

Sanitation and Prevention

Clean cultivation and ploughing equipment to help prevent spread from one field to another Management of field edges
so that perennial grass weeds do not creep in avoids reinfection. When ploughing or cultivating, avoid dragging the rhizomes back into the field.

Cultivation

During the dry season, use repeated ploughings (every 3-4 weeks) of the uncropped area to bring rhizomes to the surface for desiccation. This method will not work if the weather is not hot and dry enough. Cultivation during wet periods may make the problem worse by fragmenting and spreading the rhizomes, which can then regrow.

During ploughing, the rhizomes should be raked, harrowed or gathered into piles and removed from the field. This material can be composted, fed to animals, or spread to dry in an area outside the field.

In Haraghe, the 'dungora' is used to turn soil which is infested with rhizomatous grasses. This is a form of deep cultivation, which desiccates the rhizomes during the dry season. Rhizomes are also removed by hand from the field. This method is very time consuming, taking up to 160 man days/ha.

If tractor ploughs are available, deep ploughing when wet may temporarily bury the rhizomes but they will still survive. The problem will not be solved and infestation will continue.

Plant crops such as maize, sorghum, oilseeds, and pulses in rows to facilitate row cultivation. This will keep infestations from becoming established and spreading. A forked hoe helps to remove the rhizomes. All the rhizome pieces should be removed from the field because they may regrow if left in the field.

Competition

Noug is very good for suppressing perennial grasses. It is most effective if broadcast seeded. Shade in perennial crops such as coffee will suppress these grasses.

Mowing or Cutting

The majority of problem perennial grass weeds are encouraged by this practice, so it is not a recommended method.

Herbicides

Herbicides can be used before or after the crop is
established. If used before, a non-selective herbicides such as glyphosate can be used. In either case, the herbicide selected should be the translocating type so that it will move throughout the system of the weed, affecting all above-and below-ground parts. A non-translocating herbicide, such as paraquat, will not give lasting control, it will only burn off the tops and the weed will regrow.

If the crop is established, the herbicide selected must be selective to kill the weed but not injure the crop, e.g., Fusilade in broadleafed crops. Directed application can be used as a method of applying a non-selective herbicide, but this takes skill and care so as not to contaminate the crop. Instructions for time of application must be followed carefully when using either a non-selective or selective herbicide.

Split applications may be needed if the infestation is serious. Apply herbicide, wait, cultivate, wait until new, active shoots appear, and reapply herbicide. This technique works well before crop establishment.

A long term program will need to be followed to control perennial grasses. Although glyphosate is expensive, the good long-term results, if used properly, will make the initial cost worthwhile.

Cultivation in Combination with Herbicides

Control using cultivation alone is difficult. It usually needs to be combined with other methods. Cultivation can be used to cut the rhizomes into smaller pieces, which aids breaking apical dominance. Once all of the pieces have started to grow, the cultivation can be followed by an application of a non-selective herbicide, such as glyphosate. This is performed before crop establishment. Rainfall should follow cultivation to encourage regrowth afterwards. As described above, the herbicide can be applied first and followed by cultivation, then a second herbicide application.

Cover Crops

Weeds, present during fallow periods or between crop rows, can be replaced by a competitive, low-growing, easily destroyed cover crop. This practice can aid soil conservation, add nitrogen if a leguminous cover crop is chosen, and help to maintain organic matter. The competitive nature of a well-managed cover crop should also help to eliminate or 'replace' noxious weeds. If used during a fallow period, ploughing should begin early enough, perhaps
combined with a non-selective herbicide, to ensure the destruction and breakdown of the crop residue so as not to interfere with land preparation and seeding. Although this intensive management is not yet very common or acceptable, it can work well.

Living mulch, a forage intercrop between the rows of the main crop such as maize, has been tried experimentally with some success in several countries. This technique is also useful in perennial crops such as coffee.

**Herbicide Use Recommendations**

1. **Glyphosate**

   Herbicide trade name: Roundup
   Formulation: 360 g/liters ML
   Dose product/ha: 4.0 liters
   
   **Crop stage:** Use before planting or as a directed spray in tree crops only when old enough to have a woody stem and well-formed bark. Do not let the glyphosate touch the suckers or green bark of the coffee.
   
   **Weed stage:** Post emergence to actively growing perennial weeds. The weeds should have at least 4-5 leaves but not be too old. Do not cultivate just prior to spraying. Cultivation 10-14 days after the first application can encourage regrowth if necessary. These weeds can be spot sprayed with 4.0 liters/ha product when they reach the 4-5 leaf stage.
   
   **Remarks:** Use clean water only. This herbicide is non-selective thus avoid spray contact with leaves, suckers or green bark. Use low drift nozzles. This herbicide leaves no soil residues. Do not mix with other herbicides. Do not apply if rain is expected within 6-8 hours.

2. **Dalapon**

   Herbicide trade name: Dowpon and others
   Formulation: 740 g/kg WP
   Dose product/ha: 8.0 kg
Crop stage: Use before the crop has been established or use in potato or coffee. For use in crops, see crop herbicide use recommendations.

Weed stage: Post emergence to actively growing weeds (15 cm) which are not too mature.

Remarks: If used before crop establishment during land preparation. Spray and then cultivate 1 week later. A rainfree period of 6-8 hours is required after application.

Other herbicides used in crops

(Table after P. J. Terry, 1984)

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Weeds Controlled</th>
<th>Crops</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Couch</td>
<td>Kikuyu</td>
</tr>
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</tr>
<tr>
<td>sethoxydim</td>
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</tr>
</tbody>
</table>

*Couch = D. abyssinica; Kikuyu = Pennisetum clandestinum; Star = Cynodon sp.

1 Controlled; 0 Not controlled; -- No information
Perennial Sedges

There are many species of sedges; some are annuals and some are perennials. Perennial sedges are much more difficult to control because they can reproduce both vegetatively and by seed; thus, this section will only deal with some of the most common, difficult to control perennial species. The two most important species are *Cyperus rotundus* (purple nutsedge) and *Cyperus esculentus* (yellow nutsedge). Other important species are: *C. blysmoides, C. bulbosus, C. rigidifolius, C. tuberosus.*

These weeds are particularly difficult to remove, due to their biological features. Although not as competitive as other weeds, they do cause considerable yield reduction. They can be particularly prolific in irrigation schemes, in high rainfall areas where other easier to control annual weeds are removed, and in minimum tillage situations, as with coffee in many areas.

**Description**

All of the perennial sedges reproduce by rhizomes and tubers, or bulbs. The underground parts are important in helping to distinguish the species. The sedge must be dug up and all parts examined.

*C. rotundus* has elongated tubers in chains, a swollen shoot base with few rhizomes, rounded leaf tips and dark, purple flowers. This species reproduces primarily by tubers and sometimes seed. It is found from sea level to 2000 m. This is known as the most serious weed worldwide.

*C. esculentus* has spherical, terminal tubers, a slender shoot base with many rhizomes, finely, pointed leaf tips, and yellowish flowers. It reproduces by tubers. It is found from 1000-2500 m.

*C. blysmoides* has black almost spherical, terminal bulbs, a large number of slender, root-like stolons coming from shoot bases, and small, dark reddish-brown flowers. *C. bulbosus* is similar, but has branched stolons with terminal bulbs. These two species are usually found in highland crops, particularly coffee.

*C. rigidifolius* has rhizomes which are woody, dark, and connect daughter shoots and irregular tubers, only small swellings on the rhizomes. The leaves are shiny and tough (rigid); the flower is dark, reddish-brown to black. This species is usually found where land has not been disturbed, as in coffee and in highland pastures.
Biology

It is very important to understand the biology and the way sedges reproduce in order to design and implement effective control measures. Perennial sedges are propagated both vegetatively, with bulbs, tubers and rhizomes, and by seed. It is very important to identify which sedge or mixture of sedges is present and whether or not it is in a reproductive state at the time a control measure is applied.

The tubers or bulbs, like perennial grass perennating organs, can remain inactive or dormant for long periods of time when buried. Tubers can survive at least 3 years, if not longer, in the soil. Only a limited percentage will sprout each season. Each tuber or bulb has several active buds on it. Only one or two of the buds will sprout simultaneously; thus, if one shoot is destroyed by weeding, the tuber or bulb can resprout. This can occur an average of four times. The dormancy of the tuber or bulb can be broken in a similar manner to perennial grass rhizome buds, that is, by soil disturbance or environmental changes resulting in good germination conditions. The bud dormancy on a single bulb or tuber can be broken by cutting off the shoot of the sprouted bud early in its growth cycle.

The formation of tubers, bulbs, and flowers is dependent on environmental conditions. A combination of temperature, moisture, and day length will determine if the sedge is in its vegetative, sexual (or both) reproductive state.

As an example, the growth pattern of C. esculentus is as follows: The tuber sprouts when conditions are optimum, usually at the onset of the rains when the temperature is warm. As the rhizome originating from the tuber bud reaches the soil surface, it differentiates into a basal bulb from which the leaves, flower, roots, and other rhizomes originate. If conditions continue to be favorable, rhizomes will grow from the basal bulb and form their own basal bulbs and daughter shoots. These daughters in turn can do the same, so that eventually a number of generations from the one original tuber can be formed. If there is drought stress, shorter day lengths, or other triggers, the rhizomes will terminate in a tuber rather than a basal bulb. The infestation rate can be 1300 plants and 6900 tubers originating from the original tuber in one season.

Sanitation and Prevention

Clean tools and implements after use in infested fields to prevent the tubers or bulbs from being carried to other areas. Avoid using infested soils for growing transplants.
Cyperus esculentus (Yellow nutsedge)
Figure 12. *Cyperus esculentus* compared to *Cyperus rotundus.*

For *C. esculentus*: a) pointed leaf tip; b) terminal tubers, smaller than *C. rotundus* and edible; c) yellowish flowers with smaller, blunter spikelets; d) "daughter plants" arising from many rhizomes from "mother plant". For *C. rotundus*: e) rounded leaf tip; f) tuber larger, in chains and not edible; g) dark, purplish flowers with larger, sharper spikelets; h) "daughter plants" arising from rhizomes which are fewer in number.
Cultivation

Ploughing or digging during the dry season before the crop is planted can help to desiccate the small propagules (tubers and bulbs). This method, if practical, can greatly reduce the tuber or bulb numbers. Plough or cultivate once per month during the dry season. If the area is in an irrigation scheme, pre-irrigation can be used to encourage germination, followed by cultivation to destroy the sprouted tubers.

Controlling sedges using manual cultivation is difficult. Sedges are difficult to uproot because the shoot breaks off from the tuber or bulb and then resprouting can occur. Only diligent, continuous hoeing will control this weed, but it is seldom practical. Cultivation may be useful in preventing new tubers or bulbs from forming if it is done before the sedge becomes vegetatively reproductive.

Competitive Cropping and Mulching

Generally, sedges are sensitive to low light conditions and do not sprout, grow, or reproduce well under shade. Therefore, if possible, choose a vigorous, fast growing crop which is planted at a density to encourage fast canopy closure.

A thick mulch layer will give temporary assistance in sedge control. This is a more practical solution for tree crops such as coffee. Black polyethylene plastic is better than organic mulches, but is very expensive.

Mowing or Cutting

This method does not control sedges, but rather encourages them. Do not use it.

Cover Crops

See this section under perennial grass control.

Herbicides

Several herbicides can help to suppress sedges. Glyphosate works successfully on the sedges which have a continuous, active rhizome system (*C. rotundus*). It is less successful on *C. esculentus* because of the differing ages of the tubers. All herbicides must be used at the optimum timing in order to prevent new tubers or bulbs from forming or for preventing them from sprouting. In the case where the sedges are merely suppressed, herbicides can be used with
competitive cropping or mulch applied after herbicide application. The following table is a guide. Refer to individual crops for use recommendations.

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Cyperus esculentus</th>
<th>Cyperus rotundus</th>
<th>Others</th>
<th>Crops</th>
</tr>
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<td>potato</td>
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</tbody>
</table>

1 Partial or full control, suppression  
0 No control  
-- No information  
(After P. J. Terry, 1984)
Rottboellia

*Rottboellia cochinchinensis*, previously named R. *exaltata*, is an annual grass. It is noxious because of small hairs on its stems which cause itching and irritation, hence its common name of 'itch grass'. This feature causes people to avoid weeding the grass. It is also resistant to some of the major herbicides used in maize and sorghum where the weed occurs. It can therefore develop into a major problem. In Southern African countries, *Rottboellia* has caused up to 70% yield reductions. There are no figures available for Ethiopia at this time.

**Distribution and Description**

*Rottboellia* is prevalent in western areas of Ethiopia where seasonal rainfall is relatively high, but at lower, hotter altitudes. It occurs from sea level up to 1800 m. It is mainly found in maize and sorghum fields, which are major crops in this area, but can occur in any other crops, in fallow, or roadside areas. It can grow to be 3.5 m tall, as tall or taller than the cereal crop it infests. As mentioned, the leaf sheaths are covered with hairs which cause itching. The seed is borne in a cylindrical spike which is 5-15 cm long, which is segmented. The seed head breaks into cylindrical seed pieces which are nearly flat on both sides. It propagates by seed.

**Biology**

*Rottboellia* can grow quickly and produce as many as 3000 seeds per plant and up to 200 million seeds per hectare. The seed dies if it remains exposed on the soil surface, but can last up to 3-4 years if buried. This is a relatively short dormancy period. The seed can survive if passed through the gut of an animal. Germination begins at the onset of the rains. If the growing season is long, *Rottboellia* has the potential to produce several generations in a season. The seed shatters easily near maturity. Three weeks after emergence, the prop roots develop to help support the tall plant.

**Cultivations**

*Rottboellia* is sensitive to cultivations within 3 weeks after germination. After this time, the prop roots make it more difficult to uproot. If possible, carry out cultivations after the onset of the rains but before planting the crop. Several cultivations will encourage more *Rottboellia* to germinate and also kill the previously germinating seedlings. Plant the crop as soon after the last
cultivation as possible. If irrigation is available, pre-irrigation can be used in the same way, prior to seeding the crop. Continuous cultivation in fallowed land can accomplish the same thing.

Handpulling

Handpulling can be done without ill effects when the weed is very young. Hoeing is faster and should be performed early. Plant the crop in rows to help make this activity faster and to help in distinguishing this grass weed from the young maize or sorghum.

Prevent Seeding

Ensure that the Rottbollia which has germinated does not make seed. Hoe, cultivate, or kill with herbicide before this occurs. By following the recommendations to prevent seeding and deplete the seeds which are present, Rottboellia problems can be solved in a matter of a few years.

Minimum Tillage

If Rottboellia seed is not buried, it will die on the surface. Therefore, minimum tillage may be practical in some situations.

Herbicides

Herbicides present an economic option when the other control measures suggested above cannot be practiced because of weather or labor restrictions. For maize, pendimethalin or atrazine + pendimethalin should partially control Rottboellia. Pre-emergence (but post-planting) applications must be used to be safe on maize. Atrazine + terbutryn may give partial control on sorghum. Atrazine + metolachlor is not effective.

REFERENCES

The following references were used in writing Chapter IV and can be found in Annex 8: 13, 27, 29, 30, 34, 35, 37, 42-44, 46, 47.
Annexes
Annex 1—Guidelines When Asking Farmers About Practices Affecting Weed Presence

General Information

1. List the crops grown and the acreage they cover.

2. What is the size of the farm? Is it all in one area or in different places?

3. How far is the home from the fields? Is distance to the fields creating any problems?

4. How long has the farmer been farming there?

5. Does the farmer keep livestock? If so, does he have oxen for ploughing and cultivating?

6. What kind of changes have occurred over the years? Farming practices? Crops grown? Livestock numbers? Soil fertility?

7. Are the recommendations for producing the crop being followed? If not, why not?

8. What items (inputs) related to crop production are usually purchased? For which crops?

9. What are the average yields of the major crops?

Rotations

The previous crop, and the management practices associated with it, can affect weed species and numbers of weeds in subsequent years. This includes crop rotations as well as fallow periods.

1. What kinds of weeds were prevalent in the preceding cropping system? Is the type of crop affecting this? How?

2. How long has the field been fallow? How long has the field been in the same crop, if any?

3. What are the reasons for the rotation system the farmer uses, if any?

4. Does the farmer use certain crops in rotation specifically to help avoid weeds in crops that are sensitive to competition?
5. If herbicides are used, are there any residual effects which affect his rotation choices?

6. If the area is fallowed, is there any weed control practiced on this area? Is it grazed? Are any weeds encouraged because animals are not eating them?

Land Preparation

1. Are weeds and their residues removed before the new crop? How?

2. Is the area grazed during the dry season? Are there any weed species left? Why and which ones?

3. How is the land prepared for the various crops? How many times is the land plowed? When is it plowed? Is there a plowing strategy? (Direction, depth, starting date, etc.) How good is the seedbed? What tools are used for plowing and cultivating?

4. Is there any delay between the last plowing and planting? Why? and for which crops?

5. Are there any weed species which seem to survive the plowing? Which ones? Are any weed species given special treatment for removal? Are any weed species not removed? Why?

6. Is burning (residues or soil [guy]) used as part of the land preparation process? Why? When? What does this do for weed control?

7. Is there any pre-irrigation used for weed control?

8. Are there any weed problems (or others) related to land preparation?

Planting (for the different crops)

1. Are there any weeds present at planting time? Which ones?

2. When is planting done and why is it done at this particular time rather than earlier? Rather than later?

3. Is there a planting strategy? That is, is the planting of any given crop staggered and done on several dates? Are different methods used for the different dates?

4. What is the planting method used? What is the planting depth? Is it variable, why?
5. What is the seeding rate? What is the row spacing, if any? Is row spacing chosen with mechanical weed control in mind? Is seeding rate chosen to make the crop more competitive with weeds?

6. Are the seeds contaminated with weed seeds?

7. Are any crops intercropped? Does the intercrop help to control weeds or get in the way of weeding? How is it intercropped, relay cropped, planted simultaneously?

8. What are the labor requirements? Is there enough labor for this activity? Is this activity competing for labor needed for other jobs?

9. Are there any weed problems (or others) related to planting?

Weeds

1. What are the predominant weed species? Are there any noxious weeds which are few in number but are present? When did they become a problem?

2. Are there any parasitic weeds? On which crops and on which kind of soils?

For each important crop:

3. Which weeds does the farmer feel are the worst ones and why? What level of importance are weeds compared to other problems as seen by the farmer? By the extension agent?

4. How variable is the weed population from place to place in the area? Why? From year to year? Why?

5. How are the weeds spreading? Is there free grazing after harvest? Is this practice transferring weed seeds from one area to another? Are there particular weed species which are not being grazed?

6. Name any of the weeds hosting noxious insect or disease pests?

7. Are any of the weeds giving problems at harvest time? If yes, which ones?

8. What are the weed infestation sources (for the various species) on the farm? By animals (feed, manure), field edges, crop trash, unclean seed, irrigation water, transported from outside or between fields?
Variety Selection

1. Is the farmer using a mixture of varieties in any given field? Why?

2. Why is the farmer choosing the varieties that he is growing? Are any chosen because they are more competitive with weeds? How long are the growing seasons needed for the different varieties?

Weeding Methods (for the various crops)

1. Explain how the farmer is weeding each of the various crops. What methods are used and under what conditions? When and how often?

2. Are certain crops better weeded than others? Why? If a farmer does not weed a crop, why? Are certain weed species not weeded? Why?

3. What standard of weed control is acceptable to the farmer? Is the quality and precision good enough? Length of completion time?

4. Does the farmer stop weeding after a certain time? When and why?

5. How much labor is being used? Is there enough labor to complete the weeding on time? Are there activities which are competing for the labor at weeding time? Is the weeding done with family labor? Is the labor hired and if so how much does it cost? Is labor exchanged?

6. Does livestock availability affect the timing, type of job done, etc. for weeding?

7. What tools are used for weeding? Describe the different jobs?

8. Are herbicides used? Which ones and on which crops? Are farmers getting good results or are there problems?

9. If farmers want to use herbicides and are not, why?

10. Are herbicides available but farmers are not using them?

11. How big are the weeds and the crop when the weeds are removed? (Especially at the first weeding).

12. Are the farmers consciously using other cultural methods for weed control? Which ones?
13. Is there any damage to the crop due to the weeding methods?

14. Are there any climatic factors which delay weeding? (such as rainfall).

15. Is weeding combined with other activities, such as fertilizer application or thinning?

16. Are there any weed species which are encouraged because of the weeding practices?

**Fertilization**

1. Is the method of fertilizer application related at all to weed control? Is the method of fertilizer application making weed control worse?

2. Is animal manure used? Is it contaminated with weed seeds? Which species?

**Other uses of weeds**

1. Does the farmer feed weeds to his livestock? Are there particular species which are preferred?

2. Are any weeds used for human food?

3. Are the weeds used in compost or mulching? Are they left as an erosion control measure? What is done with the weeds which are removed?

4. Are there any other uses? firewood? housing material? medicines?

**Crop Germination and Growth**

1. Is the crop germination good or poor? If it is poor, what are the possible reasons? Is this affecting how competitive the crop is with the weeds?

2. Are there any other major pests affecting crop growth?

3. Is soil fertility a problem? What kind and why?
Annex 2—Collection of Weed and Other Plant Specimens for Identification

Three specimens of each plant should be prepared: one for the regional office, one for Shola Laboratories at Headquarters, and one for the Addis Ababa University herbarium in Addis Ababa. Either of these two organizations can also assist in identification of the species collected.

Information to Collect

It is important to collect information with each specimen. The following list explains what should be included with each specimen.

Flora of: Give country, region.

Name of species: Include Latin name if known. If not, leave a space which can be filled in when identified.

Local name: Ask the farmers in the area to give you the local name. Specify the language.

Uses or economic value: Make notes on whether the plant is edible, used as medicine, poisonous, fed to animals, used for fuel or building material, etc.

Locality: Note the woreda, peasant association, nearest village, cooperative name, etc. Describe any permanent landmarks (nearby river, mountain, etc.) If known, give the longitude and latitude.

Altitude: Express in meters above sea level. Give an approximation if not known precisely.

Habitat: Give the vegetation type (e.g., forest, grassland, farmer's field) where the plant was found. Describe the soil type (color and texture), terrain (slope or flat), wet or dry conditions, full shade or sun.

Description: Is it an annual, perennial, biennial; erect or prostate (growing flat on the ground); whether an herb, shrub, or tree? Describe the average height of the plant and variation in species, if any. Describe any vegetative features such as flower and fruit color (often this changes after dry). Describe any other characteristics which may be noticeable and useful in identification, such as kind of bark, type of branching, leaf arrangement, whether growing singly or in clumps, whether common or rare. Include only the information which make sense for the specimen you are collecting.
Collected by: Give the name of the person who collected the specimen.

Date: Give the day, month, and year and note whether it is in Ethiopian calendar or European calendar.

Place this information separately in the folder with each specimen. Make a carbon copy for each specimen. Make sure to keep one copy in case the original gets lost.

Notes on Collecting Plants

1. What to collect:

Specimens should be as complete as possible. Collect the whole plant if it is a small one. If it is large, collect a stem or stems with leaves, flowers and fruits if present. Roots need not be included unless it is a perennial species. In this case, collect underground parts (bulbs, tubers, rhizomes, etc.). The specimen will be mounted eventually on an herbarium sheet measuring 51.5 x 26.5 cm. It is crucial to collect as much as can be mounted showing the main characters of the plant. Flowers and fruits are very important; otherwise it may not be possible to identify the material.

2. How to collect

Collect plants that are dry, not wet with dew. Break if not too tough, or cut with scissors or secateurs if woody. Pick representative samples. After each specimen is collected, number it and make notes at the time of collection. A number of specimens can be collected and kept in a plastic bag for a few hours, until it is convenient to press them, unless conditions are very hot and dry.

3. How to press

Pressing is to flatten and dry the specimen. Normally a plant press is used for such a purpose. If a plant press is not available, use heavy books or objects to flatten the specimens in their folders. Arrange the plant on drying paper (newspaper) so it looks as natural as possible. Arrange so that you can see distinguishing features. Turn over one or two leaves so that the back side will be visible. If the plant is very leafy, you may have to carefully remove some of the material so the different parts can be seen. Display the flowers so that you can get different views. Large flower heads or fruits may have to be cut in half before pressing. Very thorny specimens should have their thorns broken or bent by putting the specimens
between two boards and treading on them to flatten. Do this to avoid damaging other specimens in the press.

Succulent plants must be killed before pressing, because if dried in the normal way they will continue to grow. Kill by immersing in methylated spirits or some other alcohol for an hour, or put in boiling water for 5-10 minutes, although this is not the desired method because it adds water. Press the specimen as soon as possible after this treatment.

Newspaper can be used. Place the specimen in between single sheets of newspaper. Use a double sheet as a 'drier' between each single sheet.

4. How to dry

Try to dry the specimens as fast as possible. If available, corrugated paper can be interspersed with several specimens. Replace the drying papers every day until the specimens are dry. Do not disturb the specimens in their paper folders, merely replace the double sheets in between. After one day, check the specimens and rearrange them if it is needed.

Place the press in a dry warm place but avoid excess heat. If it is very damp, place the press over a heat source. If corrugated paper is used, put the press in a vertical position so the air can circulate.
Annex 3—Herbicide Activity Chart

I. Photosynthetic inhibitors

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<tr>
<th>Inhibitors</th>
<th>Time to apply</th>
<th>Uptake</th>
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</thead>
<tbody>
<tr>
<td>a. Triazines</td>
<td>(in relation to weeds)</td>
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<tr>
<td>1. atrazine</td>
<td>PRE, early POST</td>
<td>root, foliage</td>
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<tr>
<td>2. cyanazine</td>
<td>PRE, POST</td>
<td>root, foliage</td>
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<tr>
<td>3. ametryne</td>
<td>PRE, POST</td>
<td>root, foliage*</td>
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<td>4. prometryne</td>
<td>PRE, POST</td>
<td>root, foliage</td>
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<td>5. simazine</td>
<td>PRE</td>
<td>root</td>
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<td>6. terbutryne</td>
<td>PRE, POST</td>
<td>root, foliage</td>
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<td>7. metribuzin</td>
<td>PRE, early POST</td>
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<td>b. Ureas</td>
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<td>1. linuron</td>
<td>PRE, POST</td>
<td>root, foliage</td>
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<td>2. diuron</td>
<td>PRE, POST</td>
<td>root, foliage</td>
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<td>3. fluometuron</td>
<td>PRE, POST</td>
<td>root, foliage</td>
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<td>c. Uracils</td>
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<td>1. bromacil</td>
<td>PRE</td>
<td>root, foliage</td>
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<td>d. Others</td>
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<td>1. bentazon</td>
<td>PRE, POST**</td>
<td>foliage</td>
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<td>2. bifenox</td>
<td>PRE, POST</td>
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<tr>
<td>3. ioxynil</td>
<td>POST</td>
<td>foliage</td>
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<tr>
<td>4. bromoxynil</td>
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<td>foliage</td>
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II. Mitotic Poisons

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<tr>
<th>Poisons</th>
<th>Time to apply</th>
<th>Uptake</th>
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<tbody>
<tr>
<td>a. Dinitroanilines</td>
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<tr>
<td>1. pendimethalin</td>
<td>PRE, incorporate</td>
<td>root</td>
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<tr>
<td>2. trifluralin</td>
<td>PRE, incorporate</td>
<td>root</td>
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<tr>
<td>b. Thiocarbamate</td>
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<tr>
<td>1. EPTC</td>
<td>PRE, incorporate</td>
<td>root, foliage</td>
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<tr>
<td>2. asulam</td>
<td>POST</td>
<td>root, foliage</td>
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<tr>
<td>c. Others</td>
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<tr>
<td>1. DCPA</td>
<td>PRE</td>
<td>root, foliage</td>
</tr>
</tbody>
</table>

* most common route of uptake
** most common time to apply
III. Protein inhibitors

a. Acetanalines

1. alachlor PRE, early POST root, foliage
2. metolachlor PRE foliage-
   monocot root, foliage-
   dicot
3. propachlor PRE, early POST root, foliage-
   dicot
4. pebulate PRE root

b. Amides

1. propanil POST foliage

IV. Growth regulators

1. 2,4-D PRE, POST root, foliage
2. 2,4,5-T PRE, POST root, foliage
3. MCPA PRE, POST root, foliage
4. picloram PRE, POST root, foliage

V. Cell permeability

1. paraquat POST foliage

VI. Miscellaneous

1. diclofop-P-methyl POST foliage
2. glyphosate POST foliage
3. dalapon POST, PRE root, foliage
4. TCA PRE, POST root, foliage
## Annex 4—A Guide to Recommended Herbicides and Crop Selectivity

<table>
<thead>
<tr>
<th>HERBICIDE</th>
<th>CROPS</th>
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Annex 5—Extension Action in Weed Control*

* After: Burrill and Deutsch, to be published.
### Annex 6—Sample of a Questionaire Tabulation Sheet

Please note that this is only a sample. Use it to see how categories are created and how a tabulation sheet is made. A new tabulation sheet must be designed for each questionnaire.

1. Awraja:  
   Woreda:

2. Number of cooperatives interviewed:  
   Number of individual farmers interviewed:  
   Total number interviews:

3. Amount of land (per individual family)  
   $\leq 0.25$  $0.5$  $0.75$  $1.0$  $1.5$  $2.0$ ha  
   Number responses ____________________________________________

4. Crops used: % land planted to crop  
   $\leq 10\%$  $20\%$  $30\%$  $50\%$  $75\%$  $100\%$  
   sorghum _______________________________________________  
   teff _______________________________________________  
   maize _______________________________________________  
   wheat _______________________________________________  
   barley _______________________________________________  
   chickpea _______________________________________________  
   safflower _______________________________________________

5. Time lived in area: $< 5$  $10$  $20$  $30$  $40$  More years  
   History the same __________________________________________  
   Area/crops changed _______________________________________

6. Varieties: color height season planting  
   Local name users seed (L,M,S) (L,N,S) month  

7. Main weeds: Latin name Local name

8. Crop husbandry:  
   not used shilshalo thinning leaf strip pesticides used  
   1 times _______________________________________________  
   2 times _______________________________________________  
   3 times _______________________________________________

9. Main problems:  
   Problem 1st 2nd 3rd

10. Striga problem:  
    increasing decreasing same this year only last  
    not serious few years

225
Example of Crop Activities Calendar Data Collection Sheet

<table>
<thead>
<tr>
<th>Crop Activity</th>
<th>J</th>
<th>F</th>
<th>M</th>
<th>A</th>
<th>M</th>
<th>J</th>
<th>J</th>
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</tbody>
</table>

Teff

Land preparation
1st plowing
2nd plowing
3rd plowing
4th plowing
5th plowing
others
planting
fertilizing
weeding
1st
2nd
3rd
4th
herbicide
harvesting
threshing
(continued)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Activity</th>
<th>J</th>
<th>F</th>
<th>M</th>
<th>A</th>
<th>H</th>
<th>J</th>
<th>A</th>
<th>S</th>
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</tbody>
</table>

Maize
- Land preparation
  - 1st plowing
  - 2nd plowing
  - others
- Planting
  - Shilshalo
  - Thinning
- Weeding
  - 1st
  - 2nd
  - Others
- Herbicide
- Insecticide
- Harvesting
- Threshing

Put an 'x' under each week that the activity is worked on throughout the season.

* European calendar month abbreviations
** Ethiopian calendar month abbreviations, thirteenth month not included.

This sort of calendar can be filled in during farmer interviews to help establish where there may be labor bottlenecks (labor competing for several jobs). The information can be compiled and presented like the table on the next page.
## Crop Activities Calendar Tabulation Sheet

<table>
<thead>
<tr>
<th>Crop</th>
<th>Activity</th>
<th>Months</th>
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<td>J  F  H  A  M  J  J  A  S  O  N  D*</td>
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<tr>
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<td>T  Y  M  G  S  H  N  M  T  H**</td>
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<tr>
<td>Teff</td>
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<tr>
<td>Maize</td>
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</table>
Annex 7—Maps

GROWING PERIODS

1. Short single season

This includes areas in which the growing period is adequate to meet the full water requirements of short-maturing crops in most years, but with a substantial risk that subnormal rainfall will result in serious yield reductions.

2. One distinct season

This includes areas which have an adequate growing period to meet the full water requirements of medium maturity crops in most years. The dry period is too long for perennials.

or 2 seasons with the first rain completely inadequate

Areas in which there are two potential growing periods. The second is most important. In most years the first has an unreliable onset which will jeopardize the growing of a second crop.

3. Two distinct seasons, both adequate

The includes areas where both growing seasons are adequate for rainfed crop production in most years. There are two types of areas included in this category, one where the first season is most important and the other where the second season is most important. Supplementary irrigation to bridge the two seasons may be feasible in some areas.

4. Two seasons but only one adequate

This includes areas with a double growing period but only one is adequate for rainfed crop production in most years. The secondary growing season, which can come first or second, is too unreliable for sustained crop production.

5. One long season

These areas have an adequate growing period to meet the full water requirement of long-maturing crops in most years. It is usually adequate for most perennial crops.

6. One very long season

These areas have an adequate growing period to meet the full water requirement for long or very long-maturing crops.

or Two seasons merged into one at higher altitudes or two
shorter seasons at lower altitudes. These are areas in which both growing seasons are adequate for rainfed crop and which may merge into one long single growing season.

7. **White areas**

These areas have very little or insufficient moisture for reliable crop production, even short-maturing varieties.

**THERMAL ZONES**

1. **Kolla**

The approximate temperature range is 21-26/27.5 degrees C found at 500/800-1500/1600 meters above sea level.

2. **Weyna Dega**

The approximate temperature range is from 16-21 degrees C found at 1500/1600-2300/2400 meters above sea level.

3. **Dega**

The approximate temperature range is 11/12-16 degrees C found at 2300/2400-3000/3200 meters above sea level.

4. **Wurch and high Wurch**

The approximate temperature range is 7.5 or less to 11/12 degrees C found at 3000/3200-3700/3800 or more meters above sea level.

5. **White areas**

Temperatures are greater than 27.5 degrees C at very low altitudes (less than 500-800 meters), where crop production is not likely to be successful.

*Note:* Temperature estimates refer to mean annual temperatures. The altitude ranges are country-wide averages and may vary locally.

The preceding categories of growing periods and thermal zones can be used to:

- Understand the variability of Ethiopian conditions when making recommendations and setting research priorities.
- Select weed control options for farmers growing crops under various conditions.
Understand the nature of weed competition which is influenced by both rainfall and temperature.

Single season or double season with I completely inadequate (duration 4.5 - 6.5 months)

Double season both adequate (duration 3 and 3-4 months)

Single short season (duration 2.5 - 4.5 months)

Single season or double season with 1 completely inadequate (duration 4.5 - 6.5 months)

Double season but only 1 adequate (duration 2.5 - 4.5 months and 3 - 8 weeks)

Single long season (duration 3.5 - 9 months)

Single very long season or double season merged (at higher altitudes) or 2 shorter seasons (at lower altitudes) (duration 7 - 11 months)
Thermal Zones

Attitude (m):
- 580/1600 - 1600/1680
- 1520/1680 - 2200/2400
- 2300/2400 - 3000/3200
- 3000/3200 - >3800

Temperature range:
- 21 - 26/27.5 °C
- 16 - 21 °C
- 11/12 - 16 °C
- <7.5 - 11/12 °C

Traditional home:
- Kolla
- Wayne Dega
- Dega
- Wurch and High Wurch
Annex 8—References


4. Burrill, L. C. and A. E. Deutsch. draft of Weed Control Information Guide - For Developing Countries. to be pub. by IPPC, Oregon State University, Corvallis, OR 97331.


Syria and Ottawa, Canada.


In the TCP/ETH/4532 project, the objective was to address and improve technology transfer for weed management to small farmers. The project was implemented by the Ministry of Agriculture, Crop Protection and Regulatory Department. An information base useful to extension officers for problem identification and solving must be established before relevant technology transfer can take place. Therefore, the project concentrated on production of two manuals - *Weed management in Ethiopia - An extension and training manual* and *A weed identification guide for Ethiopia*. These materials were reinforced by a 2-week training course for 50 upper-level, regional extension staff.

The project also contributed in the formation of trial/demonstration programme verifying research results on enclosed sites and on farmers’ fields. Surveys supported all work including a more concentrated effort on *Striga* control (a parasitic weed on sorghum and maize). The project also purchased equipment to assist in the running of the weed management programme. The above contributions are the first of their kind in Ethiopia. The assistance took place over a 14-month period (July 1986-December 1987).

Recommendations are to continue and expand the work. To do this, the Government may need continued external technical assistance, particularly in the Ministry of Agriculture extension area. Recommended new activities include: quarantine assistance for weed pest identification; data and survey analysis and use system; further work on *Striga* and extension methodologies including in-the-field training; formation of a more extensive technology verification network; assistance in herbicide policy justification.