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WEED CONTROL PROBLEMS IN TANZANIA

A review team report

by
S.F. Miller and L.C. Burrill

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The views and interpretations in this publication are those of the authors and should not be attributed to the Agency for International Development or to any individual acting in their behalf.

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Acknowledgment

The review team acknowledges the assistance of Paul Duffield, IITA (International Institute of Tropical Agriculture), John Anania and Bert Behrens (USAID/Dar es Salaam) in developing the itinerary and initiating contacts with key individuals. USAID/Dar es Salaam paid local travel costs for the team and IITA-USAID provided a vehicle for travel. Mr. Fred Machange, Ministry of Agriculture, accompanied the review team on all travels and provided considerable travel and technical assistance.

Summary

A review team composed of two International Plant Protection Center staff members and one Tanzanian Ministry of Agriculture agronomist spent 3 weeks visiting seed farms, NAFCO farms, private farms, and research institutions in Tanzania during April 1980 to assess current weed control practices and observe weed-related problems.

Based on observations, the team presents its findings and offers recommendations for increased training in weed science, establishment of a more formalized nation-wide weed research program, and increased attention/funding to support an expanded effort.

Suggestions for specific methods to more effectively control several of the most pernicious weed species are included. The entire socio-economic matrix of the Tanzanian small farmer needs to be considered and weed control methodologies evaluated against this backdrop.

The team recommends initiation of research in minimum tillage, stubble planting, and stale seedbed methods. Also, increased consultation and literature acquisition are advocated, with titles of suggested work in print appended.

Purpose of review

The International Plant Protection Center (IPPC) at Oregon State University was requested by USAID/Dar es Salaam to review the weed problems in Tanzania and recommend a course of action for their control. The request resulted from a telegram sent by AID Washington to all missions citing the technical assistance capabilities of IPPC working through an AID centrally funded contract. Dr. Paul Duffield, IITA, working with John Anania and Bert Behrens of USAID/Dar es Salaam, prepared the itinerary and facilitated travel arrangements.

Review team

Team members:

Stanley F. Miller, director, and Larry C. Burrill, weed scientist, International Plant Protection Center, Oregon State University, Corvallis, Oregon 97331 / USA

Assisted by:

Fred Machange, agronomist, Ministry of Agriculture, Ilonga / Tanzania

Itinerary

Thursday, March 27	-	Travel to London.
Friday, March 28	-	London.
Saturday, March 29	-	Travel to Dar es Salaam.
Sunday, March 30	-	Dar es Salaam.
Monday, March 31	-	Consultation at Ministry of Agriculture and USAID/Dar es Salaam.
Tuesday, April 1	-	Travel to Iringa.
Wednesday, April 2	-	Review weed problems at Dabaga Seed Farm (maize, wheat and barley).
Thursday, April 3	-	Travel to Mbarali NAFCO Farm (rice) and on to Mbeya.
Friday, April 4	-	Visit Uyole Agriculture Corporation; travel to Mikumi.
Saturday, April 5	-	Travel to and review Ilonga Agricultural Research Institute; review Msimba Seed Farm (maize, wheat and barley).
Sunday, April 6	-	Travel to Morogoro.
Monday, April 7	-	Travel to Arusha.
Tuesday, April 8	-	Review NAFCO West Kilimanjaro Farms (wheat, maize, barley, and beans).
Wednesday, April 9	-	Visit with personnel of Basotu NAFCO Farms (wheat).
Thursday, April 10	-	Review Arusha Seed Farm.
Friday, April 11	-	Visit Lyamungu Agricultural Research Institute (coffee, beans, and banana) and CIDA (Canadian International Agricultural Development) program (wheat); travel to Dar es Salaam.
Saturday, April 12	-	Reviewed trip, Dar es Salaam.
Sunday, April 13	-	Flew to Mtwara (could not land because of weather) returned to Dar es Salaam.
Monday-Friday, April 14-18	-	Dar es Salaam.
Friday, April 18	-	Depart.

Introduction

This report is divided into six sections. Weed problems of seed farms are discussed in section one, weed problems of farms of the National Agricultural and Food Corporation (NAFCO) are addressed in section two, weed problems of selected Research Institutes in section three, and small farm weed problems in section four. Section five is devoted to important weed species of Tanzania. General recommendations appear in section six.

I. Seed farms

Four seed farms have been created by the Ministry of Agriculture, with USAID assistance, to provide foundation and certified seed to the Tanzania Seed Company, which distributes the seeds throughout the country. The review team visited three of the four farms.

Dabaga Seed Farm

- Location: Approximately 40 kilometers* southeast of Iringa.
- Personnel contacted: Charles Bandala, co-manager.
- Ecological conditions:
  - rainfall: average 1250-1500 mm/year
  - elevation: 1700 meters
- Size and crops: 1600 acres, about 1000 of which are cropped; corn, barley, beans, sunflower, and wheat are the major crops.

*Units of measure reflect a mixture of English and metric (as encountered). There has been no effort to convert to all one system in this report.

- **Major weed problem:** Digitaria scalarum (couch grass)
- Other weeds of importance: Commelina benghalensis, Dachtyloctenium aegyptium, Setaria verticillata, Amaranthus sp., Chenopodium sp., Eleusine indica, Polygonum convolvulus, Cyperus esculentus, Tagetes minuta, Oxalis latifolia.

- Comments and recommendations: The review team observed that barley was at the correct growth stage to be sprayed with a phenoxy herbicide for control of broadleaf weeds. The relative merits of 2,4-D versus MCPA were discussed. Unfortunately, both sprayers belonging to the farm were inoperable. (Contact had been made with a neighboring farmer to borrow his equipment.) The seed farm's two sprayers were of different makes thereby preventing cannibalization of one to keep the other running. Neither had flat fan nozzles for herbicide spraying. A catalog of sprayer parts was left for reference and possible future purchase. A general discussion of spraying equipment occurred.

  Maize was relatively weed free as it had been treated with Primagram (Ciba-Geigy, 25% atrazine plus 25% metolachlor). The herbicide was applied preemergence at the rate of [illegible] l/ha and followed by tractor cultivation and handweeding as needed. The labor force comes from the surrounding area. At times a labor force of up to 400 people is required, but mostly used to de-tassel maize.

  No herbicides are used on sunflowers or beans. As the acreage expands herbicides will be required. Written suggestions on several herbicides to be tested were left with Mr. Bandala.

  The review team also suggested that the stale seedbed technique be tested in areas unaffected by Digitaria sp. This entails preparing the seedbed and then leaving it until the emergence of the first flush of weeds. The weeds are then killed by an application of paraquat after which the crop is seeded without additional tillage. Handling practices for paraquat must be sound since the material is moderately toxic. Glyphosate

(Roundup) is safer, but considerably more expensive (Sh 150/ha vs. Sh 425) at the same rate. Glyphosate has the additional advantage of controlling most perennial weeds.

Unreliable equipment constitutes a major problem for the farm. The team was advised that the situation would be resolved through a complete package of equipment to be provided by USAID/Dar es Salaam.

A side trip to the neighboring farm provided an insight into the problems of large producers in Tanzania. The farmer is successfully producing maize, wheat, barley, and beans on 1000 acres of his total 1600 acres. He uses atrazine on his maize with good results. He intended to use alachlor (Lasso) on his beans, but it did not arrive in time to be applied. The team indicated to the farmer that alachlor is an effective grass killer. Since grasses will become an increasing problem in maize if the use of atrazine is continued, alachlor and atrazine combined will make an effective treatment. Alachlor resembles metolachlor in its effects and in combination with atrazine would have similar effects to the Primagram presently being used at the Dabaga seed farm.

No herbicide is used on the farmer's barley or wheat. He relies on repeated discing and harrowing prior to planting. Very little hand weeding is done. A serious infestation of Oxalis latifolia was noted in his barley (suggested treatment of Oxalis sp. appears in a later section).

The farmer reported that his only insect problems were cutworms on beans, and stalk borer on maize.

When asked why he did not utilize his entire 1600 acres, the farmer responded that he received adequate income from the 1000. Further, he had no place to spend his money as few consumer goods are available and the purchase of new farm

equipment is restricted. Parastatal institutions have priority on all new farm equipment allowed to be imported by the government. If he would be allowed to purchase more equipment, his priority would be: 1) a tractor; 2) a combine harvester, and 3) a corn harvester.

Msimba Seed Farm

- Location: Approximately 300 kilometers west of Dar es Salaam.
- Personnel contacted: E. Iojuo, farm manager; B. Rokas, machinery specialist.
- Ecological conditions:
  - rainfall: 1072 mm/year
  - elevation: 550 meters
- Size and crops: 2500 acres, maize, sorghum, millet (finger and bullrush), sunflower, soybeans, green gram, sesame and rice. Largest area is maize and sorghum.
- Major weed problem:
  1. *Rottboellia exaltata*
  2. *Commelina sp.*
- Other weeds present:
  1. *Panicum maximum*
  2. *Cyperus rotundus*
  3. *Setaria verticilata*
  4. *Digitaria scalarum*

- Comments and recommendations: A drought this year was seriously limiting production, but in normal years weeds constitute the number one problem for the seed farm. Farm management calculates that using herbicides is less expensive than hand labor as the farm is required to pay the minimum salary of Sh 14/60 per day. Presently atrazine is used on the corn and sorghum, and chloramben on soybeans. Last year a mixture of pendimethalin (Stomp) and atrazine (Gesaprim) was used successfully on *Rottboellia exaltata* in maize, but the material was not available this year.

All purchases of chemicals are submitted to the Agricultural and Industrial Supply Corporation (AISC) which coordinates purchases of most imported agricultural inputs for the nation. An available supply of pendimethalin (Stomp, Prowl) is urgently needed for control of Rottboellia exaltata in maize. The compound also can be used in beans, green gram, and sunflower, but not sorghum. (See section on Rottboellia control). Panicum maximum and Digitaria scalarum are not serious problems, yet they are spread so easily that they should be controlled now wherever they are found. Repeated cultivation during the dry season, or an application of glyphosate (Roundup), or dalapon should be used.

The review team recommends, in addition to the general management suggestions given in section VI, that Galex (metrobromuron plus metolachlor) be tested on sunflowers. It should provide better grass control than prometryn (Gesegard) which is now being used. Switching between the two products will minimize shifts in the weed population.

Few selective herbicides are available for the control of Commelina benghalensis and Commelina africana, both of which are present on the farm. Bentazon (Basagran) should be tested at the rate of .75 to 1 kg active ingredient per hectare, if a supply can be found. Bentazon will control many annual broadleaf weeds as well as some of the Cyperus species. This herbicide may be used on maize, beans, soybeans, and rice.

Arusha Seed Farm

- Location: 10 kilometers west of Arusha.
- Personnel contacted: Charles Mmari, farm manager, Ted Lane, machinery advisor.

- **Ecological conditions:**

  rainfall: 750 mm/year

  elevation: 1500 meters

  soil: volcanic loam

- **Size and crops:** 1200 acres, wheat, maize, beans, sunflower.
- Major weed problems:

  1. Setaria verticilata
  2. Datura stramonium
  3. Nicandra physalodes
  4. Cyperus rotundus
  5. Cynodon dactylon
  6. Argemone mexicana
  7. Chenopodium opulifolium

- Comments and recommendations: Currently wheat is sprayed with 2,4-D at the rate of 1.5 l/acre. Beans are sprayed with 2 l/ac of Galex. Additionally, mechanical cultivation and hand weeding are used as needed. Atrazine (Gesaprim) at 2 l/ac (2.4 kg/ha) is sprayed on corn, followed by one cultivation. A treatment of 2 liters of Galex (metobromuron + metolachlor) per acre is applied to sunflowers. Cynodon dactylon treatment consists of repeated tillage during the dry season.

  Setaria verticillata in wheat can be controlled using dichlofop (Illoxon, Hoelon, Hoegrass) and should be tested. In maize, Setaria verticillata has undoubtedly been encouraged by continued use of atrazine. Alachlor (Lasso) or metolachlor (Dual), when combined with atrazine, gives excellent control of annual grasses including Setaria verticillata. A commercial mixture of atrazine and metolachlor (Primagram) is available. The above mentioned herbicides, when applied on dry soil and when rainfall is doubtful in the following week, should be incorporated to a depth of 1 inch with a spike tooth harrow.

An option for maize is to apply either alachlor or metolachlor preemergence to control annual grasses followed by 2,4-D postemergence to control broadleaves. However, the fields seen by the review team had so few broadleaves that 2,4-D may not be required for several years. Datura stramonium (thorn apple) and Nicandra physalodes (Chinese lantern) can be partially controlled by 2,4-D. Hand weeding or spot spraying should be used for light infestations.

Consideration should be given to alternating the use of trifluralin (Treflan) in beans with Galex. Treflan will help stop shifts of weed species while being more resistant to leaching. Control of Argemone mexicana following bean harvest could be accomplished using an application of 2,4-D, very likely with less expense than current mechanical methods.

Cyperus rotundus is a major problem on 60 acres of the farm's low land. The review team recommended an application of 2 kgs of acid equivalent per hectare of glyphosate (Roundup) applied just prior to the weeds' flowering stage. For total control, the soil should be worked 5 to 10 days after the initial application of Roundup and a second application made when regrowth nears flowering. Should insufficient moisture prevent regrowth of the Cyperus rotundus, the second application can occur the following season.

Cynodon dactylon, a serious weed on most of the farm, is being partially controlled by repeated cultivation. A comparison with glyphosate (Roundup) should be made, as glyphosate may be more economical.

Zero tillage crop production presents opportunities for the farm through reduced erosion as well as minimized

cultivation. However, an agro-economic study will be required to determine its cost, benefit and overall values.

II. NAFCO farms

Three farms belonging to the National Agricultural and Food Corporation (NAFCO) were visited by the review team. The function of the NAFCO farms is to produce food crops, which are sold to the National Milling Corporation (N.M.C.) for resale and distribution in the country.

Mbarali NAFCO farm

- Location: 250 kilometers southwest of Iringa.
- Personnel contacted: Charles Mallisa, Ag. officer.
- Ecological conditions:
  rainfall: 600 mm/year
  elevation: 1200 meters
- Size and crops: 8,000 acres, rice 6,500 acres, soybeans 1000 acres, green manure 500 acres (*Sesbania exaltata*)
- Major weeds:
  1. *Cyperus* sp.
  2. *Echinochloa colonum*
- Other weeds noted were:
  Commelina sp., *Ipomoea* sp., *Tribulus cistoides*, *Eleusine indica*, *Setaria verticillata*

- Comments and recommendations: Paddy rice is sown from October through the middle of November and harvested in April-May.

Average yield is 3T/acre. Common varieties are IR8 and IR579. Water supplied from the Mbarali River is adequate for the farm.

The general production sequence is:

1. Plowing with moldboard;
2. Flooding;
3. Harrowing;
4. Seeding;
5. Spraying fluorodifen (Preforan) 10 l/ha for pre-emergence weed control;
6. Flooding and draining for germination three times at 5 day intervals;
7. Postemergence weed control, propanil at 5 to 6 l/ha when applied early, or 10-15 l/ha when applied late; where there is Cyperus sp., add Satrol 3.75 l/ha;
8. Manual weed control, if required;
9. Flooding;
10. Fertilizer applied at:
    a. seedling
    b. tillering
    c. node elongation
    d. panicle initiation
11. Drain;
12. Harvest.

The review team was informed that the available labor supply is inadequate during the months of December-January when conflict arises between the needs of the farm and the planting requirements on the laborers' own fields. Laborers are brought in from a distance of up to 11 miles and are paid Sh 10/45 per day.

Excellent results for the control of Echinochloa colonum should be obtained by the combination of flooding,

herbicides, and hand weeding now being employed. Since control is unsatisfactory, the review team concludes that some or all of the control procedures are being improperly implemented. Since the farm is so large, this is not surprising. The team stresses the importance of uniform and timely herbicide applications.

The herbicide propanil is somewhat dependent on flooding for effective control of grass weeds. The team suspects that Echinochloa colonum is germinating and growing when the water is lowered for fertilizer application. Since this is done at four separate periods, ample time is available for germination after the initial kill. It is recommended that the water level be maintained during fertilizer application, even though broadcasting fertilizer may prove to be more difficult.

A general weed sanitation program is urgently required for the farm. Weeds along irrigation ditches and canals, road sides, and field borders constitute a continuing source of weed seeds. Glyphosate (Roundup) can be a major tool in this program because it leaves no harmful residues in the soil. In areas where rain water from treated soil will not move into the fields, atrazine can be used to control many weeds. Repeated application of paraquat can be used to stop weeds from setting seed. If vegetation is slashed or mowed, the operation should be completed prior to the setting of seed.

Oryza punctata (wild rice) is now present on the farm. The team was told that after about 3 years of rice production on a field, the wild rice population builds up to a problem level. The practice now in use involves rotating problem fields to a crop of soybeans and applying Galex (metobromuron + metolachlor). Metolachlor is very effective against wild rice and its use should be continued.

The review team was informed that the rice crop following

soybeans experiences the most serious weed problems. The situation indicates insufficient weed control in the soybeans. Since weed control is the major reason for growing the soybeans, every effort should be made to keep the crop weed free. Hand weeding should be continued to the extent possible, although labor shortages apparently occur during this period. Irrigating the soybeans encourages weed growth and moves the herbicides out of the effective level. If current practices cannot keep soybeans weed-free, the herbicide trifluralin (Treflan) should be considered as an addition to Galex. Trifluralin effectively controls grass and embodies greater resistance to movement in irrigation water than the chemicals in Galex.

All of these herbicides, plus hand weeding, make weed control in soybeans expensive, but the prospect must be considered as part of the weed control effort for rice.

West Kilimanjaro

- Location: Western slope of Mount Kilimanjaro.
- Ecological conditions:
  - rainfall: 1100 mm/year
  - elevation: 1500 meters
  - soil: red volcanic loam
- Size and crops: 1100 acres, wheat, barley, forage
- Major weed problems:
  1. *Digitaria scalarum*
  2. *Cynodon dactylon*
  3. *Cyperus blysmoides*
  4. *Setaria pallidifusca*
  5. *Amaranthus sp.*
- Also observed:
  1. *Sorghum sp.*;
  2. *Galinsoga parviflora*;
  3. *Tagetes minuta*;

4. Polygonum convolvulus;
5. Chenopodium album.

- Comments and recommendations: Rainfall distribution is bimodal with the long rains starting in March and the short rains in October. The rains at times are torrential with up to 200 mm in a single day. Strip cropping is used to reduce erosion. Each strip appeared to be 30-40 meters in width. The strips are alternately cropped the first being planted during the long rains and the second during the short.

The operation sequence is as follows:

1. Post harvest tillage; disc harrow or plow;
2. Disc harrow, 1-2 passes, after the rains;
3. Plant; March 15-April 15 during the long rains, Oct. 15-Nov. 15 during the short rains;
4. Apply herbicide; 2,4-D;
5. Harvest.

Seed is machine broadcast (discs are removed from the drill allowing the seed to fall directly to the ground) and followed by a disc harrow. A very uneven field surface results which must hamper combining. A hydraulics problem on the tractors caused the seed to be machine broadcast, the team was informed; however, it was suspected that the real cause was attempting to drill in wet ground coupled with too little tractor power.

Yields average between 900 and 1600 kg/ha (14-17 bu/ac). Fertilizer does not increase yield sufficiently to compensate for the increased costs.

Weed problems on the farm will certainly become worse. Discing perennial weeds will only spread them unless done at the right time. Use of a drill to plant directly into the soil is recommended. Presently a significant portion of the seed does not emerge and that which does produces a very irregular stand. Uneven emergence complicates and restricts the use of herbicides,

which generally must be applied at defined stages of growth. Additionally, several soil-applied herbicides can be safely used only if the wheat seed is covered by at least 1 inch of soil.

Use of 2,4-D should be continued; it should be applied at .5 kg/ha acid equivalent, after the wheat is well tillered, but before early boot stage. Since so many formulations of 2,4-D are available, care must be taken to assure the correct rate.

Some broadleaf species will probably not be adequately controlled by 2,4-D. Dicamba at 1/8 to 1/4 kg of acid equivalent per hectare should provide good control of most 2,4-D resistant broadleaves.

Dichlofop (Hoelon, Hoegrass, Illoxon) should be tested as an early postemergence treatement for annual grasses. Approximate rate would be 0.75 kg a.i. per ha.

Weed control in stubble provides an excellent opportunity to reduce the weed population. Dicamba and 2,4-D will prevent broadleaf weeds from producing seed. Alternatively, glyphosate (Roundup) at 1 to 2 kg. a.e. per hectare could be used. It will control most perennial grasses as well. Though glyphosate leaves no harmful residues in the soil, it is expensive.

For the control of Digitaria scalarum and Cynodon dactylon, the team suggests two alternatives. First, continue mechanical methods during the dry season. The procedure should be: 1) loosen the soil with a disc plow or harrow, and 2) follow with a chisel plow or spring tooth harrow at 20 day intervals. This will bring the rhizomes to the surface where they will die if the dry period is long enough. The mechanical operations must reach sufficient depth to bring all rhizomes to the surface.

Secondly, glyphosate (Roundup) could be applied to the

grasses when they are growing vigorously, but before flowering. The underground as well as the above portions of the plants will be killed. A suggested rate is 2 kg. of a.e. per hectare. One application will usually give 90 to 95 percent control. Even though high, glyphosate's cost can be amortized over many years. Reinfestation of the fields must be avoided, however.

Basotu NAFCO Farms

- Location: 350 kilometers southwest of Arusha.
- Personnel contacted: Mr. Munise, zone manager, Mr. Mgoma, unit manager.
- Ecological condition:
  rainfall: 600-700 mm/year
  elevation: 1500-2000 meters
- Size and crops: The total farms expect to produce on 42,000 acres by 1981; wheat is the major crop with some barley also grown
- Major weeds:
  1. Setaria verticillata
  2. Nicandra physalodes

- Comments and recommendations: The review team was unable to visit the Basotu farms. Thus, what is stated stems from interviews with the managers rather than observations.

The Basotu farms are divided into four units, each consisting of approximately 10,000 acres, with their own management, machinery and work force (50 workmen). Canadian International Development Assistance (CIDA) is providing basic support and technical assistance.

The production sequence is:

1. Post harvest plowing; chisel plow with points (rather than sweeps) immediately after harvest;
2. Weed; chisel plow followed by 4-5 passes with sweeps depending on need;

3. Plant; March-April with deep furrow (press) drills;
4. Spray; 2,4-D;
5. Harvest; generally swath followed by a combine with pick up attachment.

Average yield is 1300 kg/ha with good yields approaching 200 kg/ha. Grain is trucked to Arusha. Wild oat presently is not a problem. The major pests are birds. Army worms did go through in 1976.

The Lyamungu Research Institute, in cooperation with CIDA, is presently testing the following herbicides for Setaria control: Fernimine (2,4-D), Dosanex (metoxuron), Treflan (trifluralin), Stampede (nitrofen), Illoxon (dichlofop), Stam F34 (propanil), and Igran (terbutryn).

No specific recommendations are made by the review team. General sanitation, i.e., clean seed, and clean machinery, should be followed. (See comments under Management) There are very few herbicides suitable for Setaria control in spring wheat. The most promising is dichlofop (Illoxon, Hoelon, Hoegrass) which is being tested presently.

III. Research Institutes

Ilonga Research Institute

- Location: Approximately 300 kilometers west of Dar es Salaam adjacent to the Msimba Seed Farm.
- Personnel visited: Dr. Jim Deutsch, maize agronomist, and Dr. David Sperling, maize breeder, CIMMYT; Dr. Mazo Price, legume agronomist, and Dr. B. B. Singh, legume breeder, IITA; Dr. R. Jodha,

economist, and Dr. Sam Mukuru, sorghum breeder, ICRISAT; Joe Kabissa, entomologist and acting station director.

- Orientation: The institute's focus is toward the central lowlands. Primary crops of interest are beans, maize, sorghum, and cotton.

- General comments: The review team did not have a chance to see any of the institute's experimental work due to late arrival and a severe drought that camouflaged treatment differences. What follows is a summary of the comments made by the above mentioned scientists.

Rotteboellia exaltata is the major weed problem in maize. It becomes serious as soon as farmers start intensive agriculture. Encouraging results have been obtained by mechnically controlling the first flush of Rottboellia prior to planting.

The Institute uses atrazine (Gesaprim) for general weed control in experimental plots. Under prevailing conditions one application of atrazine was estimated to provide control equal to two hand weedings. No residue problem from atrazine has been noted. Frank Brockman, IITA agronomist, applied up to 10 kg per ha without toxicity to following crops. In the package of practices for small farms, the National Maize Program (World Bank) recommends a variety of maize, fertilizer rates, and two hand weedings (during the 2nd and 4th weeks in the lowlands, and the 3rd and 6th in the highlands). When the recommendations are followed in the village trials, yields of 3 T. are obtained in the lowlands and 6 T. highlands, whereas, the small farmers average yields are 1 and 3.5 T. respectively.

In the lowlands, maize weeding and cotton planting occur simultaneously causing competition for labor. As a result. maize hoeing suffers delays. Usually 8-10 person-days are required to hoe 1 hectare of maize. Very few oxen are used in the lowlands, though some are being used in the highlands. All crops are sold to the National Milling Company at a fixed price

(Sh 1/kg for maize); however, local markets do exist generally providing higher prices; for example, maize is presently selling on the local market for Sh 4-5 per kg.

Other pest problems in maize include occasional outbreaks of army worm (1 to 5 year cycle) and stock borer. Stock borers are more of a problem in the southern highlands. Generally, no yield reduction occurs in the other areas. No major disease problems occur.

The National Milling Company does not provide adequate storage for crops. Often the storage is in the open. Thus, storage pests are a major problem.

Striga sp. is a major maize problem in the south. Iringa has some, but it is minimal.

Work on legumes includes cowpeas, soybeans, green gram, and common beans with present emphasis on cowpeas. Most legumes are intercropped either with corn or sorghum. Almost no herbicide is used. Larger farms in the northern highlands (Arusha) are experimenting with alachlor (Lasso). Frank Brockman carried out some work on bean herbicides and the results are available in annual reports. The researchers think an effort should be made to develop granular formulations for bean herbicides.

Small farms ordinarily have 1-3 has. of land which is rotated. Transport is a major problem as there are few roads, and vehicles and gasoline are extremely expensive ($4.50/gal.). All agricultural products must be sold to the National Milling Company. However, local markets have sprung up where the National Milling Company has not established control. Crops may not move out of this local market area onto major highways without being sold to, or destined for, N.M.C. warehouses. Official price for cowpeas is Sh 3/kilo. Presently cowpeas sell for Sh 7-8/kilo in the local market.

The government is attempting to organize village centers to facilitate the provision of social services. The farmers are to live in the village and travel to their farms (block farming). No figures are available, but possibly 1-2 percent of small agriculture is conducted through this system. Concern was expressed for the effects of long term occupancy on the land.

Since land is generally abundant and labor not always available, animal power may increase both production and labor efficiency. Use of herbicides during critical labor periods may also be feasible.

Sorghum is grown in areas of low rainfall, and poor soils, generally as a crop of last resort; maize is preferred. Production problems are similar to maize. Grasses are the major problem. Sorghum is generally intercropped with legumes, but at times is intercropped with maize planted at the same time. In the latter case maize matures earlier and is harvested first. The stock borer is a common problem. There are few diseases that reduce yield substantially. The sorghum breeding problem at the Institute is oriented toward the development of early varieties. Grain molding is a major problem with early varieties, however. The grain of local varieties is quite hard and better adapted to storing. Birds are a serious pest.

Weed problems are very serious in cotton. Two major cotton areas--the western and the eastern--exist in Tanzania. The western is much more important. Ilonga has research responsibility for cotton in the eastern zone. Weeds are manually controlled in this zone; the Tanzania Cotton Authority (TCA) does not recommend herbicides. Various herbicides have been tested including fluometuron, trifluralin, and pendimethalin. Manual weeding generally occurs four times a year. TCA provides basic inputs (seed, insecticide, etc.); when the product is sold to TCA, the input costs are deducted and the books cleared. Insecticide

spraying, using DDT, occurs on a calendar basis as established by TCA. Cotton is monocropped and the established price is presently Sh 3/kilo.

Uyole Agricultural Corporation

- Location: Mbeya, Southern Highlands
- Personnel visited: Dr. Robert Mattson, agronomist and senior research officer; Mr. Andrewson Temu, agronomist (degree from Cornell in 1973).
- Orientation: This semi-autonomous corporation is charged with agricultural research, but since its budget depends on farm income, staff also directs a good deal of effort towards crop production on the station. Additionally, there are approximately 350 students on site working towards diplomas in agriculture. Major crops on the station are: maize, barley, oats, lupines, soybeans, and finger millet (Eleusine coracana). A dairy cattle enterprise is also maintained. Research and development of oxen agriculture for small farmers in the area has started, including constructing wooden planters and wagons. Dr. Mattson feels that tractor agriculture in the region has largely failed.

- General comments: Atrazine is used on all the station's maize and 2,4-D or MCPA on all the wheat and oats. MCPA is used on the finger millet. Major weed problems are Amaranthus sp., Galinsoga parviflora, Eleusine indica, Digitaria scalarum, Setaria verticillata, Bidens pilosa, and Chloris pycnothrix. It appeared that weeds growing in the fallow period were creating a serious problem when the land was again prepared for planting.

The team was shown a special problem of Sporobolus sp., a grassy weed growing in pastures and thereby complicating control. One possibility suggested was to try application methods using glyphosate which will allow the tall grass to be treated, but not the pasture grasses. Various kinds of applicators, such as the "wick" applicators now being used in the U.S., were described to staff.

Lyamungu Research Institute

- Location: Southern slope of Mount Kilimanjaro, at approximately 1300 m elevation.
- Orientation: Coffee and bananas; also serves as headquarters for a Canadian International Development Agency (CIDA) research team working in the Basotu and West Kilimanjaro areas.
- Personnel visited: Dr. Semuguruka, acting director; D.L. Kessy, coffee agronomist.

- General comments: Major weed problems in the plantation crops are *Cyperus rotundus*, *Digitaria scalarum* and *Oxalis latifolia*. Also noted were two other *Oxalis* species, *corymbosa* and *corniculata*. Goalmix, a mixture of dalapon and Goal (oxyfluorfen) was giving good control (at 10 kg/ha) on all major weeds in experimental trials. Gramoxone (paraquat) is the only herbicide presently used by small producers.

  Coffee yields at the institute average between 500-700 kg/ha of clean coffee, about average for the area. Good yields can reach 1500-1600 kg/ha. Sixty kg/ha of nitrogen is applied to coffee in three applications during the year. Most small farmers intercrop bananas and coffee although the practice is not recommended by the Lyamungu Research Institute.

  Major insect pests include the leaf miner and stem borers. Leaf rust is the major disease.

Tropical Pesticide Research Institute

- Location: Arusha
- Orientation: All tropical pesticide research
- Personnel visited: E.L. Ritoine, head Botany (Weed) Division; M. Lyatuu, botanist.

- General comments: TPRI was funded by the East African Economic

Community prior to its dissolution. Since then it was reestablished as a parastatal organization of the central government of Tanzania. Its responsibilities include research on all pesticides and the development and regulation of pesticide control laws.

Weed control research falls under the responsibility of the Botany Division. The staff consists of two senior research officers, two taxonomists, and several laboratory support personnel. Both taxonomists were stationed in Kenya, but returned to Tanzania when the community dissolved.

TPRI has published recommendations for weed control on many major commodities. Present research emphasis in weed control focuses on two major weed species, Striga and Oxalis.

There are six Oxalis species with O. latifolia being the most common. Oxalis spp. are common throughout the Arusha-Moshi area in shady, moist environments. They are quite common in coffee and bananas. Yield loss from Oxalis competition has not been determined Glyphosate, EPTC, Mowdown (bifenox), paraquat, and Goal (oxyfluorfen have been tested. A paraquat and Goal mixture (1.5 l and 6 l/ha) gave effective surface control; however, complete control has not been observed to date.

IV. Small farmer weed control

Modern weed control poses a major dilemma for agriculture in developing countries. On one hand it promises to achieve production increases through relaxing labor constraints and through control of certain noxious weeds. On the other, modern weed control is potentially one of the most labor saving innovations in modern agriculture and, as such, may exacerbate employment problems not only for the landless, but

also for small farmers who periodically sell their labor to neighboring large farms. What emerges from the dilemma is the realization that the selection of an efficient and socially acceptable weed control system requires a thorough understanding of the physical, economic, and social realities of the particular region of concern.

Previous economic research, has revealed that economic efficiency gains accrue from technology adoption which (1) is economically superior to traditional technology, and (2) conserves scarce resources while intensifying the use of abundant resources. In the U.S., labor scarcity, reflected in high wage rates for agricultural labor relative to land and capital, resulted in farmer adoption of machine-intense technology. In the Far East, Japanese farmers faced with extreme land scarcity adopted biological technologies in the early 1900's to enhance land productivity and, since 1950, small scale machine technology. The latter resulted from more abundant, and thus cheaper, capital and increased labor requirements of industry. While many developing countries are faced with relatively abundant labor, scarce capital, and increasingly scarce land, this does not appear to be true in many parts of Tanzania. Scarce capital and abundant labor in the aggregate are evident. However, land is abundant, not scarce, even though some is of poor quality.

Evidence exists which suggests that labor constraints during peak demand periods limit the amount of land small farmers can farm. Also, the enterprises of the farm compete for labor, often resulting in untimely weed control and low yield, e.g., cotton must be planted simultaneously with hoe weeding corn. Thus labor availability, even though abundant at times, limits acreage expansion and yield. This suggests the need for some form of labor saving technology which might be a cheap form of mechanization such as animal traction, or the use of economically efficient and cheap herbicides.

Herbicides can also play a role in small farm agriculture where certain weeds are inadequately controlled by manual methods (hoeing or rogueing). By and large, these weeds are either perennial or parasitic. The most common perennial weed problem observed by the review team was

couch grass, Digitaria scalarum. This grass cannot be effectively controlled by manual methods and is difficult, if not impossible, to control by mechanical means. Parasitic Striga spp., also cannot be controlled by manual or mechanical methods. Striga infestations are common in several important agriculture zones in Tanzania.

The typical Tanzanian farmer utilizes 1-3 hectares of land. Maize is the preferred food crop which is generally intercropped with a legume, e.g., common beans, cowpeas, chick peas, green grams. Sorghum and millet substitute for maize in drier areas. Coffee or cotton is the principal cash crop. In theory, input and output prices are controlled by the government. However, local markets for food products flourish with prices, often four to six times the controlled price, that respond to supply and demand. The annual cash income of most small farmers is extremely low (Sh 400-500); it might average Sh 10,000 if a cash crop is produced.

Often, small farmers have one or two cows and a small flock of goats. No work animals are used. Transportation is a major problem both for the farmer and his family, and constitutes a major marketing constraint, even for local markets. Credit is in short supply, though available for coffee and cotton inputs through the government companies. However, it is virtually non-existent for food grains.

The life of the Tanzanian small farmer is not much different than most small farmers in developing countries. His one advantage is that generally additional land can be obtained. Often this is also true in the areas of "block farming" discussed earlier.

Before a small farmer will alter weed control (or any other) technologies, he must be convinced that the change coincides with his goals and objectives and increases family welfare (more production, higher net income) or reduces risk or susceptibility to risk. Manual weed control techniques are known to small farmers while modern weed technologies are not. To gain adoption of the latter, farmers must be convinced of the advantages and then taught how the techniques are effectively employed.

The process implies need for creditable applied research and a satisfactory communication or extension system.

When small farmers have cash crops--coffee or cotton--more than likely he has apparatus for spraying insecticides. The same sprayer could be used for herbicides. Moreover, in areas where an identified cash crop exists, small farmers are most progressive and have already started utilizing herbicides.

Improved weed control technologies need not necessarily involve herbicides. Multiple cropping, by maintaining a close ground cover, can generate shade that controls many weeds. Mulches also can be used by the farmer with similar effect with the added benefits of moisture conservation and erosion control. However, since forage is in short supply during the dry season in Tanzania, crop residue may not be available to form the mulch.

A key point hinges on the small farmer's interest in total farm production and resulting income, rather than production of particular individual enterprises. To the extent that enterprises compete, he may be willing to produce less of one if, by so doing, he compensates by increasing income from another. The entire farm must be considered, not only individual enterprises, in the process of defining weed control recommendations.

V. Control of important weed species of Tanzania

Rottboellia exaltata

Rottboellia exaltata is a very vigorous annual grass capable of growing taller than most crops with which it associates. Brittle hairs on the leaf sheaths cause irritation to the skin. The many

seeds rarely survive in the soil longer than 3 years. The presence of this weed has increased dramatically in Africa, S.E. Asia, and Latin America.

R. exaltata was reported to be a problem only at Msimba Seed Farm of the farms visited by the review team. However, experience suggests that the weed will spread to other areas of Tanzania if not properly controlled. Agronomists on all the seed farms, NAFCO Farms, and research institutes should be alert for the first sign of R. exaltata so that prompt measures can prevent it from becoming established.

There are conflicting reports as to the extent R. exaltata will germinate after a crop has become established. Clearly, under some conditions there are repeated weed flushes in the crops following each soil disturbance. Often the late weed flushes serve as the major source of weed seed for following crops. Where moisture conditions allow, delaying planting until the first flush of weeds can be removed aids control. Mechanical removal methods tend to encourage more seeds to germinate; a non-residual herbicide, such as paraquat or glyphosate, can be used. The crop is then seeded without disturbing the soil.

After the crop emerges, R. exaltata growing between the rows can be controlled by cultivation; incomplete control will result if the weed is allowed to reach 2 inches in height. In some cases R. exaltata populations become so thick the crop is hard to find. Cultivation or hand weeding becomes very difficult under these conditions. Weeds within the row can be controlled by cultivation if enough soil is hilled around the crop to cover the weeds (the crop must be higher than the weeds). Alternatively, weeds can be manually controlled if labor is available and at a justifiable cost.

Several herbicides will control R. exaltata. The most effective selective herbicides are in the dinitroaniline family, trifluralin (Treflan) being the best known example. Others are benefin, dinitramine, fluchloralin, isopropalin, and pendimethalin. These compounds can be used safely in most bean crops, cotton, and many vegetable crops, but

not in maize. An exception for maize is pendimethalin (Prowl, Stomp, Herbadox) marketed by American Cyanamid. Pendimethalin has a rather narrow safety margin when used on maize, but for plantings of fairly uniform depth, it can be used effectively and safely. Pendimethalin should not be used on sorghum.

Sice R. exaltata seeds last no more than 3 years in the soil, a rotation to crops which will tolerate the dinitroaniline herbicides should be considered.

No other herbicides selectively used on maize will control R. exaltata. However, paraquat (Gromoxone) can be employed effectively under certain conditions. The maize, or sorghum, must be taller than the weeds and the weed cannot be more than 2 or 3 inches high. These conditions exist most often when the first flush of R. exaltata has been controlled by other means and the crop is well established before the second flush of weeds emerge. Paraquat at only .2 lb/a will control R. exaltata if applied not later than the two leaf stage. This is a fairly inexpensive treatment.

Digitaria scalarum (couch)

Digitaria scalarum, a perennial rhizomatous grass, was repeatedly ranked as the most serious problem weed. It is spread by equipment and moves into the field from borders and roadsides. Small patches rapidly become large patches. The species holds particular significance to small farmers who must attempt to control it with only manual means.

Current control practices on mechanized farms consist of deep plowing or discing followed by periodic passes with a chisel plow to bring rhizomes to the soil surface for desiccation, a theoretically sound, effective practice. Realistically conditions in Tanzania frequently are not conducive to realization of acceptable results from the method. In the dry season soil can become too hard to be worked. When there is sufficient soil moisture to till the soil the

rhizomes will not dry sufficiently to be killed. Under these conditions the weed is spread rather than controlled. The increasing cost of fuel and shortage of tractors renders repeated tillage questionable.

Three herbicides can control D. scalarum as well as other perennial grass: dalapon (Dowpon), glyphosate (Roundup), and asulam (Asulox). Dalapon should be applied at about 8 lb a.e./a when the grass is growing rapidly. Dalapon is not selective for most annual crops; also, its soil residues will cause injury to crops for a few weeks to several months, depending on environmental conditions. Tests should be conducted under local conditions to determine the soil life of dalapon. Control will rarely be complete and follow-up treatments should be planned.

Glyphosate should be tested at between 1.5-3 lb. a.e./a (.5 to 1 gal). It too should be applied when the grass is growing rapidly. While glyphosate is very effective at controlling most perennial grasses, spot treatments should be planned for areas where control is not complete. Glyphosate does not leave any harmful residues in the soil.

Asulam (Asulox) should be applied when the grass is at least 15-20 cm tall. Rates of 3-6 lb. a.i./a should be tested. Maximum penetration into the leaves is obtained when the herbicide is sprayed at least 4 or 5 hours prior to rainfall. Asulam cannot be used in most annual crops. It would have to be used either when the land is out of production, or as a spot treatment where weedy grass is preventing any crop from growing.

In certain situations an application of herbicide followed by periodic cultivation in the dry season will produce the most economical control.

A perennial grass like D. scalarum becomes worse over time if not controlled. If uncontrolled, it will spread until infested areas become useless for farming. The expense of control measures, while high, reasonably may be charged against more than one year's production costs.

Oxalis latifolia

Oxalis latifolia occurs widely in northern Tanzanian coffee plantings; it was noted to be an increasing problem on the Dabaga Seed Farm near Iringa. While the review team was told that O. latifolia rates as a serious problem in coffee, no data emerged to indicate that the weed can effectively compete with coffee for moisture or nutrients. If this information has not been chronicled, then research logically should be conducted to assess the economic importance of O. latifolia before devoting resources to finding control measures.

O. latifolia is not easy to control. Drying the bulbs is not effective. Many herbicides will kill the foliage, but not the bulbs. The Weed Research Organization in England has data suggesting that the diphenyl ether herbicides family is fairly effective against the bulbs. The group includes oxyfluorfen (Goal), bifenox (Mowdown), nitrofen (TOK), and acifluorfen (Blazer). At Lyamungu, the review team was told that acceptable control of O. latifolia was obtained in research plots using a mixture of oxyfluorfen and dalapon, available under the trade name Goalmix.

The team saw a heavy stand of O. latifolia in a field used for annual crops at the private farm near Dabaga Seed Farm. The farmer was not too concerned and said he uses two or three harrowings prior to planting barley. He does not use any herbicides in his barley.

VI. General recommendations

Weed science training

Most of the farmers, researchers, and administrators to whom the review team talked listed weeds as their worst problem. The remainder ranked weeds, along with equipment failures, as their greatest problem.

It is obvious that weeds are interfering greatly with the operation of research stations, seed farms, and NAFCO farms, as well as small farms. These problems will become more important as additional inputs are added to the production system; improving the crop environment of necessity improves the environment for weeds.

As the importance of weeds increase, so will the need for trained weed control specialists. This demand cannot be satisfied by general agronomists. Weed control is a science and is far too complicated to expect a general agronomist to conduct weed control research and produce usable recommendations. Presently there are over 200 commercial herbicides on the world market. Each chemical is unique as to the spectrum of weed it controls and its effect on the environment. There are additional hundreds of combinations of the various herbicides, each with many brand names. 2,4-D, for example, is known by over 300 brand names. Further complexity arises in considering the array of cultural, biological, manual, and mechanical alternatives to weed control. The review team is aware of only one trained Tanzanian weed scientist, Fred Machange. TPRI has two researchers in weed control as part of the Botany Department. However, both are botanists with limited weed control experience.

To satisfy the increasing demand for weed scientists, the review team proposes the following program:

1. During the next few years a cadre of four or five government staff personnel should be selected and sent for advanced training in weed control. Preferably, the persons selected will have 2-3 years of prior research experience in one of the plant science fields. They should be sent to a university with a strong weed science orientation to both temperate and tropical crops and with the capability of providing additional support upon their return to Tanzania. The review team recommends that when the students return, they be given a regional responsibility to conduct research and provide technical advice to researchers, NAFCO farms, seed farms, and other farms within their assigned region.

2. A training program in weed control procedures and research techniques, should be presented to researchers, NAFCO farm supervisors, and seed farm managers. The training course should be from 2-3 weeks long; further, it should be held at a time and place that would insure maximum participation. The International Plant Protection Center (IPPC) of Oregon State University has conducted this type of course in other countries in Latin America and Southeast Asia. (A report of a recent course held in the Philippines is available from IPPC.)

Consultation

Periodic expatriate weed control consultation in Tanzania will be required for the next 5-6 years. Initially it will be necessary to develop and implement a weed research program utilizing existing GOT personnel. As the Tanzanian trainees return from abroad with advanced degrees in weed science, a more sophisticated program can be developed and implemented. However, consultation should be continued since most recently trained personnel need assistance in the development phase of new programs. Once the program is operational, periodic reviews should be conducted by a consulting team, until the point where the effort gains adequate momentum.

Literature

An extreme shortage of weed control literature throughout Tanzania was evident to the review team. While this is understandable given the stage of development for Tanzania, it need not continue. A considerable amount of literature relevant to Tanzanian conditions is available and several major publications will be available in the near future, notable among them, "Weed Control in East Africa," by John Terry. IPPC has prepared a recommended list of general weed control literature (appendix). Each research institute should have access to these materials. Also, a modified literature list for the NAFCO and seed farms is included in the appendix.

Minimum tillage

The review team discussed minimum tillage techniques with most NAFCO and seed farm personnel. Shortage of large tractors, high fuel costs, and soil erosion helped stimulate the interest. There are many different versions of minimum tillage crop production. Some seem to have merit in certain situations observed in Tanzania. The following comments may be useful to those wishing to experiment with one or more systems.

Stale seedbed or delayed planting; the term refers to the practice of removing the first flush of weeds without disturbing the seedbed and without bringing new weed seeds to the soil surface to germinate. Under this system a smooth seedbed is prepared in the conventional way. The field, instead of being planted, is left until the first flush of weeds has reached 1-2 inches in height. This requires only a few days of adequate soil moisture. Then weeds are killed using a nonpersistent herbicide; paraquat is fastest and cheapest and very effective against annual weeds.

Glyphosate is slower, but just as effective. The latter compound has an advantage; it controls numerous perennial weeds, but the limited regrowth of perennial weeds would not allow maximum translocation of the herbicide to the underground parts. Glyphosate's disadvantage lies in its considerably greater expense, compared to paraquat. Neither herbicide leaves active residues in the soil. Planting can take place a day or two after spraying.

The system is particularly attractive for crops where no good selective herbicide exists. Under the right conditions delayed planting can be very effective; very few weeds will germinate after planting.

Stubble planting refers to the method of planting a crop directly into existing crop residues with no intervening soil disturbance. Two major advantages result, 1) savings in time and fuel required to prepare a seedbed, and 2) reduction in potential for soil erosion. A positive side effect may be the reduced time lag between harvesting the crop and planting the next.

The system relies heavily on herbicides for two stages of controlling unwanted vegetation. The first occurs in the stubble where all volunteer crop and weed growth must be controlled. Several herbicides could produce this control. If the period between harvest and planting is fairly long, a herbicide treatment with some soil persistance may be suitable. Dalapon and 2,4-D are examples of herbicides that, when sprayed separately or together, control many grass and broadleaf species. The chemical residues from this treatment will generally not last more than 3 or 4 weeks unless very dry, cool weather prevails. Paraquat will control most annuals and seedling perennials without leaving any active soil residue. This versatile herbicide works fast. Glyphosate is another very useful herbicide, particularly where perennial grasses are a problem in the stubble. If the grass can be allowed to grow until it is near flowering stage, glyphosate will provide maximum control while simultaneously controlling all the annual weeds.

The second stage involves weed control in the crop to compensate for the absence of cultivation. With maize the use of a persistent but safe herbicide such as atrazine, along with paraquat during the stubble phase, has produced excellent weed control in the stubble and in the maize. Most of the normal non-incorporated selective herbicides can be used in the crop stage just as they would be in a conventional system.

Planting equipment may be a limiting factor for minimum tillage in Tanzania. With certain soil and moisture conditions, conventional disc type planters and drills are satisfactory. Special equipment will be necessary in certain cases. A number of row crop planters are available on world markets as are triple disc drills with a leading coulter to cut through plant residues. Only experience will determine specific equipment needs.

Management

The review team emphasizes the importance of sound farm management. In one way or another, almost every farm operation has an effect on weed growth and subsequently on crops. The large seed and NAFCO farms face

difficult management problems. Proper management, though, can control, reduce, and prevent weed problems. Clean seed, controlling weeds during fallow periods, spot treatments in fields where problem weeds are present in small areas, timely cultivations, and crop rotations must be used. Herbicides rarely control all weeds. Thus, supplementary cultivation and hand weeding should be used where possible. An integrated approach not only reduces the effect of the weeds on the crop, but prevents the remaining weeds from producing seed to infest future crops. Perhaps even more important is the prevention of a build-up of those weed species which are partially or totally resistent to a herbicide. All of the seed farms and NAFCO farms visited are using atrazine on maize. If it is not followed with mechanical weeding, the weed population will soon shift to a nearly solid stand of Setaria verticillata. In some cases this has already happened. The substitution of a proven grass herbicide like alachlor (Lasso), or metolachlor (Dual) for part of the atrazine also will prevent this particular shift from taking place.

To reemphasize a point, herbicides must be applied at the correct time and rate to be effective. A few days delay can mean the difference between excellent or inadequate control. The size of the NAFCO and seed farms makes timely application difficult. Each farm should be equipped with enough field sprayers to minimize equipment failures.

The review team did not observe any herbicide applications and thus collected no visual evidence of incorrect herbicide application. However, experience has shown that the concepts of sprayer calibration, active ingredient, acid equivalent, and rate recommendations often lead to incorrect herbicide rates. An observation of cone-type nozzles on sprayers being prepared for herbicide application hints that the equipment is not thoroughly understood.

A shortage of water with suitable quality for spraying appears to be a problem in some regions. Impurities in water not only wear out pumps and nozzles, but reduce the effectiveness of certain herbicides. Simple filters or settling tanks seem to help. Hand held spinning disc, controlled droplet applicators may have usefulness for some small farmers in

Tanzania, especially in water scarce areas. There are large spinning disc heads now available that can be mounted in series on conventional or special sprayers. These would be useful for spraying 2,4-D in large, water deficient areas like Basotu. Unfortunately, the equipment is not completely perfected as yet. Its development, however, should be followed.

Periodic cultivation of perennial grasses will continue to be an important control measure. Farm managers should be reminded that this method only works when the soil is dry and when the cultivation is deep and repeated. Performed improperly, the method spreads weeds instead of controlling them. A plow or disc harrow should be used first to loosen the soil. Following operations should be with a flexible shank implement such as a spring tooth harrow. The vibration of the teeth brings the roots and rhizomes to the surface.

Appendix

Weed Science Publications

A list of publications on weed science follows which will be useful to the overall weed control effort in Tanzania. It is recommended by the review team that the University library at Morogoro and each of the research centers should have or acquire all of the listed publications and make them available to staff and students.

Each of the NAFCO Farms and seed farms should have those items marked with an *.

John Terry, a staff member of the Weed Research Organization in England, is preparing a book, WEED CONTROL IN EAST AFRICA. It will probably be published in Kenya. Dr. Terry has considerable experience in East Africa which should make this a most useful book.

Anderson, W.P. 1977. WEED SCIENCE: PRINCIPLES. 598 p. Hardback, English. $25. West Publishing Company, St. Paul, MN / USA.

Holm, LeRoy, Donald L. Plucknett, Juan V. Pancho, and James P. Herberger. 1977. THE WORLDS' WORST WEEDS, DISTRIBUTION AND BIOLOGY. 609 p. Hardback, English. US$35. University Press of Hawaii, Honolulu, HI / USA.

Holm, LeRoy, Juan V. Pancho, James P. Herberger and Donald L. Plucknett. 1979. A GEOGRAPHICAL ATLAS OF WORLD WEEDS. 389 p. Hardback, English. US$35. John Wiley & Sons, 605 Third Avenue, New York, NY 10003 / USA.

Mercado, Beatriz L. 1979. INTRODUCTION TO WEED SCIENCE. 292 p. Paperback, English, US$9, SEARCA, College, Laguna / Philippines.

Zimdahl, Robert L. 1980. WEED-CROP COMPETITION, A REVIEW. 195 p. Paperback, English, US$9. International Plant Protection Center, Oregon State University, Corvallis, OR 97331 / USA.

Matthews, G.A. 1979. PESTICIDE APPLICATION METHODS. 334 p. Hardback, English, US$50. Longman Inc., London / U.K.

Fryer, J.D. and Shooichi Matsunaka (Eds.). 1977. INTEGRATED CONTROL OF WEEDS. 262 p. Hardback, English, US$19.50. University of Tokyo Press, Tokyo / Japan.

*Ivens, G.W. 1971. EAST AFRICAN WEEDS AND THEIR CONTROL. 250 p. Paperback, English, US$7. Oxford University Press, Oxford / U.K.

Anderson, R.N. 1968. GERMINATION AND ESTABLISHMENT OF WEEDS FOR EXPERIMENTAL PURPOSES. 236 p. Hardback, English, US$5. Weed Science Society of America, 309 West Clark Street, Champaign, IL 61820 / USA.

*Anon. 1979. HERBICIDE HANDBOOK OF THE WEED SCIENCE SOCIETY OF AMERICA. 479 p. Paperback, English. Weed Science Society of America, 309 West Clark Street, Champaign, IL 61820 / USA.

*Anon. Annual. WEED CONTROL MANUAL. Paperback, English, US$10. Meister Publishing Co., 37841 Euclid Avenue, Willoughby, OH 44094 / USA.

Ashton, F. and A. Crafts. 1973. MODE OF ACTION OF HERBICIDES. 504 p. Hardback, English, US$24.95. John Wiley & Sons, 605 Third Avenue, New York, NY 10003 / USA.

Kearney, P.C. and D.D. Kaufman (Ed.). 1969. DEGRADATION OF HERBICIDES. 394 p. Hardback, English, US$18.75. Marcel Dekker, Inc., 95 Madison Avenue, New York, NY 10003 / USA.

Klingman, G.C. and F.M. Ashton. 1975. WEED SCIENCE PRINCIPLES AND PRACTICES. 431 p. Hardback, English, Approx. US$15. Wiley-Interscience, 605 Third Avenue, New York, NY 10017 / USA.

Miller, J. (Ed.). 1972. RESEARCH METHODS IN WEED SCIENCE. 198 p. Paperback, English, US$4. Southern Weed Science Society (US), Agric. Extension Annex, Univ. of Georgia, Athens, GA 30601 / USA.

Fryer, J.D. and R.J. Makepeace (Eds.). 1977. WEED CONTROL HANDBOOK VOL. I PRINCIPLES. 510 p. English, Hardback, US$31. Blackwell Scientific Publications, Osney Mead, Oxford OX2 OEL / U.K.

*Anon. 1977. AGRICULTURAL SPRAY NOZZLES & ACCESSORIES. 33 p. Paperback, English. Spraying Systems Co., North Avenue at Schmale Road, Wheaton, IL 60187 / USA.

*Fraser, Frank and Larry C. Burrill. 1979. KNAPSACK SPRAYERS. 32 p. Paperback, 29-A-79, English, US$3. International Plant Protection Center, Oregon State University, Corvallis, OR 97331 / USA.

*Burrill, L.C., J. Cardenas, and E. Locatelli. 1976. FIELD MANUAL FOR WEED CONTROL RESEARCH. 59 p. Paperback, 20-A-76, English, US$5. International Plant Protection Center, Oregon State University, Corvallis, OR 97331 / USA.

*Yarish, W. RECOGNIZING HERBICIDE ACTION AND INJURY. 58 p. Paperback, Agdex 641-7, English. Alberta Agriculture, Edmonton, Alberta T5K 2C8 / Canada.

*Anon. 1978. MISAPPLIED ROW CROP HERBICIDES SYMPTOMS AND PROBLEMS. 12 p. Paperback, English. Cooperative Extension Service, Iowa State University, Ames, IA 50011 / USA.

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