WEED SCIENCE
IN THE DEVELOPING COUNTRIES OF THE WORLD

A REPORT

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"If you are late in doing
one thing in agriculture
you are late in all things"

Cato, 200 BC

I. INTRODUCTION

This report is based on the reports of six survey teams which visited 32 countries during 1971 and 1972. Each team was composed of a weed scientist, entomologist, nematologist, and plant pathologist. Much valuable information was gained but the short stay in each country was not sufficient to acquire a detailed picture of all weed control problems. In most cases, the study teams formed their opinions and recommendations from conversations with persons visited rather than from direct observation of field problems.

The individual reports, edited to compose this report, make it clear that it is impossible to generalize the weed problems of the world. There is great agricultural diversity and the diversity of economic resources, cultural traditions, and the present state of the art preclude neat categories.

In his paper "The Role of Weeds in Human Affairs"[1] Dr. L. Holm has stated the familiar aphorism that weeds have been man's constant companions since he gave up the life of the hunter. He then goes on to say that "there is no one in our age who stands tall enough to fully grasp the significance of weeds in the lives of people." Dr. Holm began with the proposition that "more energy is expended for the weeding of man's crops than for any other single human task.

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[1]Holm, L. 1971. The Role of Weeds in Human Affairs. Weed Science 19:485-490.

Because it is one of man's principal occupations, the burden is intricately woven into the fabric of his family and community life and to lift it up from the tangled skeins of his existence so that we may examine it, or judge it, is well nigh impossible." The authors of this report wholeheartedly concur with these general statements concerning weed science in the developing countries of the world, and we urge the initiation or strengthening of research programs in weed science.

We wish to acknowledge, with gratitude, the valuable assistance of all contact persons. The quality of the information herein is, in large measure, related to the cordial reception of the team visits and the free exchange of information that occurred.

II. REGIONAL REPORTS

A. MEDITERRANEAN BASIN

Jordan
Lebanon
Portugal
Spain
Tunisia

1. GENERAL

The development of weed science in the southern Mediterranean basin will soon follow advances that have occurred in more developed agricultural areas. These changes may occur in a shorter period because of the migration of laborers to urban areas and industrialized European countries. For example, Spain has 3 million citizens working overseas while Tunisia loses 20,000 workers each year who accept jobs in Europe. Therefore, the net result is that labor for weed control is less available to land owners and farmers. Other methods of weed control need to be explored if agricultural production is to be maintained and expanded.

More specific is the need to stress the principles of weed competition. The critical period in crop competition is during the first month of the growing season in rapidly growing crops or the first 2 to 2½ months in slowly developing crops. Therefore, when annual and perennial weeds are allowed to grow the first 1 to 2 months after crop planting, so that animal forage can be obtained, crop yields will be substantially reduced. A major part of this crop yield loss from weeds could be eliminated if early weed control practices were stressed. Farmers must be shown the direct correlation between weed dry matter production and crop yield loss. An area of land with associated environmental conditions has the potential of producing a given amount of plant dry matter, and if weeds constitute 20% of that production, crop yields are reduced by 20%.

Another area of weed control needing attention is in solid-seeded crops such as cereals, including rice, where hand-weeding is not feasible. The use of inexpensive phenoxy herbicides for selective control of broadleaf weeds has increased wheat yields in Tunisian experiments from 38 to 165%. Ford Foundation officials in Lebanon found the benefit cost ratio of spraying Mexipak wheat with 2,4-D was 15 to 1. One reason for this is that these short-strawed wheat varieties are not as competitive with weeds. The increased use of phenoxy and other herbicides in cereals, would not replace laborers and would increase cereal yields.

The benefits from non-tillage methods of weed control in citrus orchards in Lebanon are typical of those that can be achieved when all components of weed control technology are employed:

a. Weed control costs were reduced to 20% of original costs and competition was eliminated.
b. Minor element deficiencies have been eliminated by removing the weeds.
c. Soil permeability to water was increased.
d. Irrigation berms can be left undisturbed.
e. Aeration through orchards was increased.
f. Citrus tree roots were not destroyed by tillage.
g. Citrus yields have increased and yearly production is less variable.

There are only one or two weed scientists trained at the graduate level in each of the Mediterranean basin countries. Ford Foundation and FAO (Food and Agriculture Organization of the United Nations) have no personnel engaged in weed science. The few trained individuals are finding private employment financially more attractive than public employment. Trained personnel will be of paramount importance in the Mediterranean area because weed science needs are going to develop rapidly due to reduced labor supplies and demand for food will increase.

2. JORDAN

Major weed control methods used in Jordan until the past several years have been hand pulling, cutting, tillage, and cultural methods. As the labor supply to farmers becomes more scarce and expensive, they are eagerly looking for less expensive and less time-consuming methods. Integrated weed control methods must be investigated if crop yields are to be maintained and increased as many cereal and irrigated crop fields are severely infested with weeds.

Weed control research in Jordan started in 1968 with a project on controlling weeds in wheat. This has resulted in greater efforts to control weeds in cereals with about 5,000 acres now being treated with 2,4-D. Within the past two years there has been one research man in

Jordan hired for weed control research and one in plant taxonomy. All herbicides are now applied by the government. Farmers are eager to accept improved weed control procedures but are hampered by the lack of equipment and herbicides.

3. LEBANON

The first weed science research in Lebanon was initiated in 1959 and concerned weed control in cereals where hand weeding was not feasible. Present research work is largely on Orobanche spp., taxonomy of weeds, and screening of herbicides in major crops. Most weed control is still done by hand or by cultivation.

Salaries of unskilled agricultural laborers have about doubled over the past 10 years. Present labor needs in agriculture are being met by the seasonal influx of approximately 30,000 agricultural workers from Syria. Even with these immigrant laborers, agricultural labor needs are often deficient and farmers are looking for more efficient and economical means of controlling weeds. This is shown by the increased use of herbicides in cereals, citrus, and bananas. About 90% of these herbicides are applied by commercial applicators.

4. PORTUGAL

Portugal is a rapidly developing country and with this has come increased labor costs and a decreasing supply of farm labor. When this trend advances, traditional methods of hand hoeing of weeds become obsolete and other methods of weed control become necessary.

In spite of the fact that the wages of farm laborers in Portugal have risen about 6 fold in the past decade, it has been estimated that Portugal lost over 1 million workers in 1971 due to migration to other countries paying higher salaries. This has resulted in a severe shortage of farm laborers and farmers have had to change traditional production practices to maintain crop yields. A typical example of this would be changes in grape production where random plantings requiring hand hoeing have been changed to row plantings where cultivation can be used to control weeds. The consumption of herbicides increased 13 fold from 1961 to 1970 and doubled from 1970 to 1972, but mechanical methods and hand labor still predominate.

There is an embryonic core of trained weed scientists including one Ph.D. in a university teaching role.

5. SPAIN

Spain is experiencing a labor shortage in agriculture that was first recognized in about 1965. Most weed control prior to 1965 required manual labor, but there has been a necessary shift toward other methods. This is shown by the fact that herbicides now represent about

20% of all pesticides used. The extent of this shift is directly related to herbicide use becoming economical due to increased wages.

As Spain becomes more urbanized, integrated weed control systems will have to be developed for the major crops to replace the large dependence on manual labor. These changes must occur rapidly if crop production is to remain competitive in Spanish agriculture. The Ministry of Agriculture recognizes the importance of weeds and indicated that losses from weeds were greater than losses from insects and plant diseases. Therefore, the Ministry is subsidizing herbicide use. They also spray herbicides on wheat and allow farmers to observe the results in order to increase acceptance of the practice.

6. TUNISIA

Tunisia is a developing nation that is putting great emphasis on increasing agricultural production during the next 10 years. Some of the challenges it faces are a low level of farmer education, many small land holdings, a large variety of crops, widely varying climatic and edaphic conditions, and a decreasing supply of farm labor. Farmers are complaining of a labor shortage as people are moving to the city to gain shorter working days. Also important in this rural exodus are better schools and hospitals, more entertainment, and a more socially accepted vocation in urban areas.

The minimum wage of a Tunisian farm worker 10 years ago was 0.3 dinars (approximately 60¢) per day for 200 days work. Now it is at least 0.65 dinars (approximately $1.30) per day for 300 days work per year. This trend of increasing salaries for unskilled laborers is expected to increase greatly. Laborers needed for weed control work in agriculture are in short supply and will continue to decrease. This will force emphasis on other methods of weed control whereas hand and mechanical methods now predominate.

Most herbicides now used in Tunisia are inexpensive phenoxy materials used for selective control of broadleaf weeds in cereals. Wheat and barley production have been marked for increased attention and weeds are a major production problem. Weed losses in wheat average more than 20% and many fields are completely lost to weeds. In 1972, 1.2 million acres of wheat were treated with herbicides and the Extension Division is attempting to increase this to 1.8 million acres in 1973. Herbicide use will increase at a faster rate than other pesticides.

B. CENTRAL AFRICA

Ethiopia
Ghana
Kenya
Mali
Niger
Nigeria
Senegal
Tanzania

1. GENERAL

Subsistence agriculture predominates in central Africa with few monetary inputs, or improved methods, and with little capital return. Weeds are one of the major deterrents to expanding agricultural production. Programs to solve the weed problems must recognize and be compatible with the existing pattern of agricultural production and the inevitably slow pace of change. At present there is abundant rural labor to handle most weed problems in a subsistence agricultural economy. However, this picture could be changed by increasing the number of hectares each farmer handles. Controlling weeds by hand limits the number of hectares he can till and if this number is to be increased from the current 1 to 3 to even 5 to 10 hectares, improved weed control practices are necessary. As a first step more efficient cultural practices such as cultivation using animal power should be encouraged. The use of herbicides should be considered in the early stages of crop growth to allow a farmer to seed a larger area.

Herbicides are already being used extensively in coffee, cocoa, and cotton plantations, where the inputs and capital returns permit improved methods. As more industry and urbanization develop and the need for increased agricultural production by fewer people becomes necessary weed control programs will become more important. However, large scale mechanized programs and the widespread use of herbicides for weed control do not seem feasible with the availability of current rural labor and the lack of alternative sources of employment. Current agricultural programs are and should continue to be labor intensive until alternate employment is available.

In certain areas, if the current production practice of mixed cropping is changed and more mechanical clearing is done, the damage produced by soil erosion in open land will necessitate the use of herbicides to minimize soil disturbance.

The two major weed problems observed in the countries visited were nutsedge (Cyperus esculentus L. and Cyperus rotundus L.) and witchweed (Striga spp.). Hand labor has reduced populations and

competition but has not provided effective control. Striga spp. is an important weed problem on millet and cowpeas which are grown throughout the region. A rotation of millet and cowpea is not successful in the reduction of Striga infestations which still cause a 50% yield reduction of millet and nearly complete loss of cowpeas. In areas where more moisture is available, sorghum is a major crop and is also infested with Striga. The wide distribution of this pest makes quarantine impossible. It is especially prevalent on sandy and intermediate soils but not on soils with more than 30% clay.

Surveys of the weed problem and the competitive nature of individual species in each ecological and cropping system zone would be a major step toward control of each problem weed.

Studies of the ecological shifts in weed populations as cropping systems or rotatios change or in current continuous mixed cropping programs are needed to discern future problems and necessary control programs. As herbicides are introduced there will be shifts in weed populations. While ecological shifts have not occurred widely under current production practices some are apparent. Slash and burn culture encourages a shift, within a few years, from a broadleaf to a grass infestation. The primary grass weed was Rottboellia exaltata L.f.

The use of herbicides throughout equatorial Africa was very small and primarily limited to plantation crops. There was no work on integrated control systems. The problem of weeds which serve as hosts for crop insect and disease organisms was unrecognized.

Research in weed control at the experiment stations visited was quite limited. There are no trained weed scientists except at the International Institute of Tropical Agriculture (IITA) in Nigeria and at one station in Ethiopia. There were programs at the Institut de Recherches Agronomiques Tropicales et des Cultures Vivrieres (IRAT) and at IITA where herbicides were being evaluated. At present it is important that production agronomists and crop specialists be concerned with weed problems as they involve a complete cropping pattern. These programs should find places for proven chemicals in current and changing cropping systems rather than evaluate new chemicals.

2. ETHIOPIA

From the Ethiopian farmer's point of view, weeds are the most important agricultural production problem. There is some herbicide research being conducted on cotton and citrus at the Melka Werer Station. Water hyacinth [Eichornia crassipes (Mart.) Solms] is a problem in canals and irrigation water throughout much of Ethiopia

and should receive attention in the near future because of the speed of its propagation and the magnitude of the potential problem.

Weeds produce 30 to 35% yield losses in many crops. Labor costs are low and hand weeding will continue as a method of weed control but the first 3 to 4 weeks after emergence are the critical time and hand labor is not adequate for the task. It appears that there is some possibility of using herbicides in the early stages of growth followed by hand weeding later in the season. This would allow for an increase in commercial scale operations in certain crops.

3. GHANA

The primary organization for weed research is the Council for Scientific and Industrial Research (CSIR). Within this group there is a weed committee that meets regularly to discuss and outline weed programs. However, there is very little being done because there are not enough trained people.

The research coordinated by the research control committee of CSIR deals primarily with the toxic effect of herbicides in soil, plants, and people and secondarily with effects on ecological balance. The research, to date, has been on chemical control but there is a move to include biological methods. The chemical companies sell directly to the user, however, the largest user is the government through the research institutes. There is no registration of chemicals but the committee which includes industry representatives does prepare a list of recommended chemicals.

In certain crops such as cocoa, herbicides are being used for weed control, however, in most crops they are not because of cost. Paraquat is being used to a limited extent on cocoa plantations and can be a valuable management asset. At the Crops Research Institute at Kumasi there is no one directly concerned with weed control but some testing is done. In certain areas there is some use of corn herbicides by the larger farmers.

The evaluations of herbicides are very limited. There are a few knapsack sprayers used for application of herbicides. These are primarily in the cash-crop areas and there is little possibility of use at the peasant farmer level in view of current cost.

In general, there is no information concerning the losses produced by weeds nor the levels of infestation of the various species. Rottboellia exaltata L.f. is a developing problem in areas where intensive slash and burn agriculture is practiced. The development of programs for herbicide use in the mixed crop economy of the forest region will be difficult.

4. KENYA

The weed problems in East Africa are well outlined in the book "East African Weeds and Their Control" by G. W. Ivens (Oxford University Press, 1967).

Coffee, cotton, and tea are the most important cash crops. Maize is the most important subsistence crop in Kenya and where maize is grown on a large scale, there is limited use of the herbicides atrazine and 2,4-D. 2,4-D is also used on wheat. Because of cost, small growers have not yet begun to use herbicides although they are readily available. In general the small holders are carrying out hand-weeding practices and the estates are using herbicides such as paraquat for effective control particularly in coffee and tea plantations. At present there seems to be indiscriminate use of pesticides and there is no mechanism for recommendations. Registration legislation is currently being considered. All herbicides were sprayed by hand.

5. MALI

The major agricultural products are millet and cattle. Land is available but labor is limiting in millet production. As in most of central Africa, there is nothing known about the extent of the weed problem or the degree of weed competition offered by particular species. Broadleaf weeds do not seem to be a problem because they are controlled by hand labor. A small amount of herbicide testing related to weed problems in cotton is being carried out by the group at the Institut Francais de Recherches Fruitieres Outre-mer (IFAC).

6. NIGER

There has been some limited testing of herbicides at the IRAT Station. The present agricultural system cannot support the use of any pesticides because there is limited capital output from subsistence agriculture. There is a need for more effective weed control for one month or so after planting to allow a farmer to handle or plant more acreage. The competition for labor in this early period is a problem.

Agricultural extension is poorly developed and hampered by a lack of trained personnel and money to support extension programs. The extension effort is most productive when a commercial crop is involved.

Some research on the nature of the Striga spp. problem has been done in the sorghum and millet production areas of Western Niger. They have found some control from heavy applications of nitrogen and

increased plant populations. Striga seemed to be more prevalent in dry than wet years when valley lands flooded. Host plant resistance or tolerance may be appropriate solutions but little research is being done.

7. NIGERIA

Dr. Keith Moody of IITA is conducting weed control research. His studies indicate that the greatest limitation to farm size is weeds and that 70 to 80% of the farmers' time is spent weeding. Much of the weeding is done poorly and late, after 60 or 70% of the yield reducing damage has occurred. Competition studies conducted at IITA indicate that the first three or four weeks are most critical from the standpoint of weed competition. There are a few herbicides used in plantation crops such as coffee and cocoa but they are not in general use because of cost. In Nigeria there are only three distributors for atrazine and availability of herbicides is limited. There is no legislation for labeling or registration of pesticides.

Primary weed species of western Africa are described in a book by J. K. Egunjobi, "Some Common Weeds of Western Nigeria." In Nigeria aquatic weeds are not a problem in big lakes because of constant water turnover but are a problem in small ponds.

8. SENEGAL

The IRAT research station at Bambey is conducting research to screen new herbicides. Improved fertility practices in certain areas have merely complicated the weed problem by providing conditions for improved weed growth. In general, hand labor is sufficient to handle most weed problems, however, there are situations where labor is not in the right place at the right time. This is particularly true in the first two or three weeks after emergence of the crop. Herbicide use in Senegal has been estimated by the researchers at the IRAT station at about 1,200 kilos per year. Because of the problem of slow degradation, some research is being done on herbicide carryover in soil.

9. TANZANIA

The Tropical Pesticide Research Institute is the only organization in east Africa or in all of central Africa doing significant weed research. Their recommendations are published to the Ministries and include evaluations of laboratory, greenhouse, and field experiments with herbicides. They also collaborate with the Ministries in demonstration trials throughout east Africa. The herbicide section in EAFRO has been operational for 10 years and is now the strongest section. They are concerned about herbicides in the environment and the resultant residue problems.

C. CENTRAL AMERICA

Costa Rica
Guatemala
Guyana
Honduras
Nicaragua
Panamá

1. GENERAL

Personnel engaged in weed science research in the public sector agencies (Universities and Ministries of Agriculture) in Central America and Panamá have not been trained professionally in weed science. Most researchers have an Ingeniero Agrónomo (Ing. Agr.) degree; one held a Master of Science degree from a university in the United States; one had European training. None of these academic experiences were in weed science. These researchers hold limited memberships in professional organizations in weed science or other associated disciplinary areas. Most incumbents have a tenure of 1 to 3 years in weed science positions and carry other research responsibilities. Only one has been involved in weed control projects since 1966 continually on a part-time basis. The less than total grasp these workers have of weed science and its role in overall food crop production probably is related to a high personnel turnover rate in the public agencies.

It is doubtful that the average person engaged in weed science in the private and industrial sector is better trained, but it is obvious that he has greater motivation.

Personnel now active in weed science have been trained pragmatically through experience; their capabilities and qualifications are neither uniform nor adequate for strong weed science programs.

Basic weed science research programs were neither observed nor reported. Applied weed research in public agencies is oriented toward specific crops. Some countries have weed control projects in the Ministries of Agriculture and in the Facultades de Agronomia of the University.

Duplication of effort is occasional and a relatively high degree of inter-agency cooperation was noted. Applied weed research programs become markedly discontinuous under frequent personnel shifts. Programs appear national; no international programs were observed except for the Oregon State University, International Plant Protection Center - USAID contract (IPPC) in support of and coordinating national programs. The IPPC program has had a modest effect in attacking weed problems but it cannot yet be labeled successful. Chemicals, equipment, and some practical training have

been provided. These efforts fall short of desirable goals and can become successful only when directed through trained persons with reasonable tenure at the national level.

Agrichemical companies appear willing to assist the public agencies by providing commercial and experimental herbicides and, in some cases, limited equipment. Agribusiness and weed science activity focuses on practical demonstration-experiments designed to provide a basis for sales.

Information on the acreage and scale of food crop production was not readily available. Few public agency interviewees had a complete understanding of plant protection needs for crop production.

Weed control experiments have been conducted in many food crops, but much of it has been sporadic and inadequate to provide widely applicable data or recommendations. Invariably, research facilities and equipment are modest and consist of a chemical storage/workroom, measuring and dispensing laboratory utensils, a small-plot sprayer, often supplied by IPPC, and back-pack, hand-pumped commercial sprayers. Few field sprayers are available.

Library facilities are modest and few herbaria are available. Few research units have more than modest weed collections. Botany, including systematics and plant physiology, and agronomy, including weed control, are normal offerings in the Ing. Agr. curriculum. The University of Costa Rica (UCR) offers a course in weed control.

Few countries have a recent or complete flora, however numerous monographs prepared by National, North American, and European botanists are available. Available weed flora tend to consist of brief and incomplete lists, often poorly organized. Interviewees generally had inadequate knowledge of the weed flora pertinent to their food crop and research areas.

Researchers in several countries are developing data on cultivation (weed-free period) requirements and on crop loss through weed competition. Essentially no information is available on crop losses attributable to weed competition. Most researchers were aware of the possible relationships between weed hosts and crop plants and could cite "white fly virus" symptoms, but none of the interviewees could cite specific information.

Statistics on herbicide importation and field use were difficult to obtain. Only agrichemical businesses seemed to have information on amounts imported and commercial application rates and methods. Experimental and field data for food-crop herbicides generated by public agencies appear inadequate for sound recommendations and extension activity. Information on herbicide carryover and soil residues, weed tolerance, weed population shifts, and other herbicide use problems is minimal. Weed control publications are few and incomplete. Extension activity, as with field development, is more within the purview of

agribusiness than public agencies. Some chemical practices effective in food crops and suggested or recommended have dubious legal status in countries which regulate agrichemical usage.

2. COSTA RICA

The weed science research effort in Costa Rica appears stronger than in the rest of Central America and at least one man has full-time responsibility for the University weed control research and teaching activities. There is a very harmonious relationship among the Ministry of Agriculture, University, and other autonomous governmental agencies like the Consejo Nacional de Producción. The Ministry and University weed science research programs cooperate with the Oregon State University International Plant Protection Center program. Private chemical companies conduct herbicide demonstration experiments in food crops with export possibilities. As in other Central American countries, only minimal herbicide performance data are available. Private sources indicate that Costa Rica imports almost 40% of the herbicides entering Central America and Panamá. Most of the herbicides are destined for coffee and rice.

Comprehensive weed flora listings are not available, but a partial listing of individual weeds and suggested controls is used in the UCR weed control course. Information on effects of and economic losses attributable to specific or general weed infestations in Costa Rican food crops has not been developed.

3. GUATEMALA

Discussions with Ministry of Agriculture officials and managers of the coffee and cotton growers associations demonstrated that these persons do not consider weed control an important input in food crop production. The value of chemical weed control methods in the more important cash and export crops--coffee, corn, cotton, sugarcane, and pasture was acknowledged. Abundant, inexpensive agricultural labor facilitates decisions favoring the use of labor and using available cash or credit for other production roles.

Weed science research facilities and equipment are limited. Basic information on the crop-weed interactions is not sufficient for food crop management programs. Chemical supplies of experimental and commercial herbicides are readily available through numerous U.S. and European agrichemical companies operating in Guatemala. Apparently, public agency weed science research is conducted only by the Ministry of Agriculture through one Ing. Agr. assisted by an undergraduate student. It is likely that a minimum of ten agrichemical company employees conduct on farm herbicide trials, particularly in export crops. It should be noted that the weed science training and formal experience of these persons is minimal.

A staff botanist at the University of San Carlos maintains a national herbarium. Weed science is not curriculum material in the Ing. Agr. educational cycle. The Ministry of Agriculture program in weed science currently consists of field experiments to evaluate herbicide performance in crops located at experiment stations in the several crop/climate zones.

Prior research was conducted by the University alone, but the current program is supported by the IPPC program. The IPPC provides technical advice, experimental weed control equipment and chemicals, and some visual and training aids through a Central American coordinator based at the OSU/USAID mission in El Salvador.

Guatemala's diverse geographic/climatic zones promote a diverse weed flora. Preparation of a handbook of the weed flora of Central America is being coordinated by IPPC. Quantitative data on specific crop loss through weed competition and consequent economic loss are not known. Specific weed hosts for diseases, insects, nematodes, or viruses attacking local food crops have not been evaluated. Specific weeds important in some crops have been noted. Other than the ubiquitous nutsedge "coyolillo," most of these weeds are among the Compositae, the Euphorbiaceae, or the Gramineae. Increased populations of herbicide-tolerant Euphorbiaceae and Gramineae appear to be associated with repeated commercial herbicide usage. The flora in coffee plantations, weeded with paraquat and 2,4-D, has shifted toward tolerant species. Unfortunately, observations of plant population changes have not been recorded.

Herbicides are important in Guatemala but accurate statistical information is not available. No published recommendations for herbicide use are available from public agencies. A sound extension program is not possible under these conditions. Herbicide development has been most active by commercial interests for the export crops--coffee, cotton, and sugarcane. Corn and rice receive the bulk of food crop herbicides. Weed control in a large, but ill-defined acreage of pasture is obtained through rotary mowing or tractor-sprayer application of chlorophenoxy herbicides.

4. GUYANA

There are no trained weed scientists in Guyana. Weed control in sugarcane is the responsibility of an entomologist with Bookers Corporation. Weed control in cane is generally accomplished with herbicides and 2,4-D is commonly used. Herbicide recommendations are based on field experiments and experiences gained from similar situations abroad.

5. HONDURAS

There are no trained weed science personnel in the public sector and it is probable that the private sector lacks trained technicians. The Escuela Agrícola Panamericana (EAP) at El Zamorano has a trained botanist and a trained agronomist who instructs in weed science.

Weed science input in food crops by the public sector is minimal and is cooperative with the IPPC program for Central America based in El Salvador. Use of chemical weed control methods in food crop production is part of the EAP teaching and sustenance programs. Private chemical companies have conducted some herbicide demonstrations in "exportable" food crops like corn and rice.

There is no national flora, and the only effective herbarium is at EAP. A publication of EAP contains line drawings and descriptions of 40 weeds important to El Zamorano area. Major weed problems of Honduran food crops and production areas have not been determined nor has information on weed competition and economic losses.

Numerous herbicides are imported into Honduras. One agrichemical importer projects that the use of herbicides in Honduras will increase from U.S. $212,500 in 1972 to U.S. $250,000 in 1976.

Information basic to the sale and rational use of herbicides is not apparent. Recommendations for herbicide use and other weed science publications do not appear to be available from either public or private sources except for specific food crop uses in the EAP weed identification bulletin.

6. NICARAGUA

There are few personnel trained in weed science in public agencies; it is probable that some technicians in the private sector and in agricultural support organizations--like the Banco Nacional--may have had exposure to some training.

Public agency input in applying weed science to food crops is modest and is cooperative with the IPPC program. National agrichemical distributors and international chemical companies are active in applied weed science on farm demonstrations, particularly in exportable cash and food crops.

A course in general botany, including taxonomy, and an agronomy course which includes weed control are part of the Ing. Agr. curriculum at Escuela Nacional de Agricultura y Ganaderia (ENAG). Botany, including plant systematics, appears to be offered at Universidad Nacional Autonoma de Nicaragua (UNAN) at Leon. Apparently there are several herbaria; all in poor condition. There is no single national flora but numerous national and foreign publications

have catalogued Nicaraguan plants. A listing of the most common weeds of annual crops, pastures, irrigation canals, and forests has been prepared by ministry personnel and is used in ENAG courses. The major weed problems of Nicaraguan food crops have not been evaluated and weed competition and economic loss data are not available for cash or food crops.

Herbicides are commonly used in export and large-scale food crops; virtually all irrigated rice is weeded with herbicides. Herbicide sales and use appear to be based on farm demonstrations conducted by agribusiness personnel. Herbicide use recommendations and other weed science publications were not available from public or private agencies.

7. PANAMÁ

The public agricultural research sector in Panamá employs two part time people but no personnel trained in weed science. The private sector lacks trained technicians but conducts much of the field research work. The public sector research effort in food crop weed control is minimal and is cooperative with the IPPC program.

A herbarium is maintained by the UP Facultad de Ciencias. A weed flora for Panamá is not available, but many important local weeds are listed in "Tropical Weeds" by Cardenas, Reyes, and Doll; published in 1972 by the IPPC South American program and the Colombian Agriculture Institute (Ed. F. Pardo).

Some information has been developed on the yield response of corn and rice to cultivation schedules and weed competition. Economic loss data were not available. Many herbicides are imported into Panamá for rice and other large acreage high value crops and for pasture. Herbicide prices appear reasonable by U.S. standards. Public agency recommendations may be found in occasional publications but most recommendations are developed by the chemical industry.

D. SOUTH AMERICA

Bolivia
Brazil
Dominican Republic
Ecuador
Uruguay

1. GENERAL

Due to widely varying conditions, it is impossible to generalize on the state of weed control in the countries visited. However, broadly speaking, weed science programs were all deficient

in financial support, equipment and supplies, trained personnel, library facilities, intra- and inter-institutional communications and data exchange, clearly defined long range goals and plans [The National Agricultural Research Institute (INIAP) of Ecuador may be an exception], and an effective means of disseminating information to the user.

Other common deficiencies include lack of information documenting economic losses caused by weeds, overdependence on herbicides in research programs, lack of information on the biology and ecology of especially serious weeds, and few studies on the dynamics of the weed flora in modernized agricultural systems.

Many of the above deficiencies could be resolved if the respective governments could provide adequate financial support for agricultural research. The problems of communication, planning, and dissemination of information can best be solved by strong program leaders who have the support of supervisors. Without this support at the top level, it is unrealistic to expect enthusiasm and esprit de corps among program personnel. No broad regional programs have been identified due to the diversity of conditions encountered in each country. Improved communication via participation in the Latin American Weed Science Society (ALAM), inter-institutional information exchange, attendance at national and international meetings, etc. would aid individual workers in their respective programs, but it is felt that ultimately the weed control problems can best be resolved through specific programs in the respective countries.

2. BOLIVIA

There is no organized weed control program within the government supported institutions. Approximately ten weed control experiments have been conducted within various production programs of the Ministry of Agriculture during the last five years, resulting in very preliminary data. There has been no coordination of experiments between these programs. Trained weed control specialists and financial resources for a research program are seriously lacking within the Ministry of Agriculture and universities.

Although documenting data are not available, weed caused crop losses are considered serious in the sub-tropical and high valley areas. When herbicides were used in a recent wheat experiment at the San Benito Experiment Station, Cochabamba, production was increased nearly 30%. Sociological problems may limit modernization of weed control methods in the Altiplano region, but there is an immediate need for aggressive efforts in other parts of the country. Due to the large expansion of cotton acreage (from 8,000 to 70,000 hectares since 1969), hand labor is becoming scarce and more expensive

in the area. An additional factor limiting the efficacy of hand weeding is the fact that many crops are planted with the initiation of the rainy season. Frequently, fields are too wet to enter for manual weed control practices for several weeks. It is precisely during these first 20-40 days that weed competition is most critical in the majority of crops.

Large areas are being cleared for crop production in the sub-tropics. After two or three years of cultivation a dramatic change is noted in the weed complex, as grassy species predominate over broadleaf species. The aggressive grassy species obligate most small farmers to abandon fields and move to new lands. However, rapid settlement of the zone is restricting this alternative. Herbicides and advanced weed control methods are becoming a necessity if economical production is to continue.

There is a pressing need to initiate a program to catalog and study the biological and ecological aspects of the changing weed complex. This effort will become increasingly important as a more intensive agriculture develops. Several very serious grassy weeds (Rottboellia exaltata L.f., Sorghum halepense (L.) Pers., Imperata sp., and Trichachne spp.) are becoming established in localized areas. An in depth biological-ecological study would aid in establishing a program to prevent the spread of these weeds throughout the area.

3. BRAZIL

Weed control is one of the most recently developed facets of plant protection in Brazil. Less than 40 people are engaged in weed control research and teaching in Federal and State Institutions and less than 10 of these are full time. In fact, personnel involved with weed control activities in these institutions have decreased during the past 15 years.

Meanwhile, the use of herbicides is rapidly increasing, due mainly to the efforts of the chemical industry. All companies which actively market herbicides in Brazil have some type of "on farm" product testing programs conducted by salesmen or special agents. Several companies maintain their own research farms for the specific purpose of testing herbicides and other pesticides.

Within the various Federal and State supported institutions conducting weed control research, most efforts are directed at elementary field testing of commercial products to obtain data for making recommendations for usage. With the exception of the Instituto Agronomico, Campinas, most experimentation is limited in scope and provides a minimum of what must be considered essential information. Economic analyses were lacking in all of the research data reviewed.

A National Herbicide and Weed Control Society exists with approximately 250 members, the majority representing industry. However, the society suffers from a lack of funds. In addition, a National Herbicide and Weed Commission has been established to coordinate and standardize weed control research among all State and Federal institutions. National priorities are established annually and uniform field experiments are conducted at all locations. Researchers are also encouraged to work on local and regional problems not included in the national priorities.

The limited number of persons active in weed science stems largely from a general lack of awareness of the importance of this field plus lower salaries at the State institutions as compared with industry. Prior to 1969, weed science courses were not offered in any university in Brazil. A one-term course is scheduled as an undergraduate elective in four universities. A fifth university has included an undergraduate course in weed science in its 1973 curriculum and plans a graduate level course in 1975 coincident with the return of a professor currently studying for the Ph.D. degree in the United States. A basic weed science textbook has also been published by the University of Sao Paulo, at Piracicaba. Among Brazilian weed researchers, few have studied outside of Brazil and none have obtained more than the M.S. degree.

The basic infrastructure necessary for solving the weed control problems in Brazil already exists. Of primary importance is the training of young men who will be able to assume leadership roles in the near future since the majority of the present leaders are near retirement age. Increased financial support should enable the Ministry of Agriculture to attract these capable leaders and resolve the existing resource gaps.

4. DOMINICAN REPUBLIC

Due to the weed control advances obtained principally through the sugarcane and chemical companies, the Dominican Republic is enjoying a degree of weed science competence found only in Brazil and perhaps Ecuador. However, adaptive field research at government institutions is very deficient. One contributing factor has been the dilution effect of requiring present Ministry personnel to work in several fields, frequently outside their areas of training.

The majority of all pesticides used in the Dominican Republic are herbicides. Some 70-75% of all sugarcane acreage is treated with herbicides. Approximately 25-30% of the sugarcane acreage is cultivated by small traditional farmers (Colonos), who rely mainly on hand weeding and a very low level of other technical inputs. Production per unit area by the colonos is about 50% of that obtained by the large plantations.

5. ECUADOR

A good infrastructure has been developed in the present INIAP weed control program and the enthusiastic young scientists are developing a program to adequately cope with the weed control needs of the nation. INIAP should continue graduate level training of additional personnel, outside of Ecuador, as well as the short term training of younger researchers with Centro Internacional de Agricultura Tropical (CIAT).

Losses due to weed competition have been documented in most annual crops, averaging from 15 to 20% with traditional control methods. Panicum maximum Jacq. and Cyperus rotundus L. are two of the most serious weeds encountered in the lowlands. Water weeds, especially Eichhornia crassipes (Mart.) Solms have the potential of becoming serious problems in many rivers and canals in the lowlands. Weed control recommendations for some major crops will be issued in 1973 and others will follow. There is a high degree of cooperation between the INIAP research centers in developing recommendations and solving problems.

6. URUGUAY

Weed control has been neglected in Uruguay. Only two persons are actively engaged in weed control research in the Ministry of Agriculture. Private sugarcane companies have done research but their results and recommendations are not available to the public.

The limited weed control research in Uruguay stems from a general unawareness of the seriousness of the problem. At the National University, weed control research and teaching have been virtually nonexistent. Crop losses due to weeds, while known to be extensive in most crops, have not been documented. The high prices of herbicides and their limited availability also suppress the development of adequate programs. The most fundamental need is for the decision makers to become aware of the importance of the weed control problem.

E. SOUTHEAST ASIA

Malaysia
Philippines
Taiwan
Thailand

1. GENERAL

The green revolution in Southeast Asia has intensified problems with weeds as well as other pests. The new, short, early-maturing, fertilizer responsive rice varieties compete less effectively with weeds than later-maturing, less fertilizer responsive, taller varieties. Light which penetrates the canopy in plantings of the new

varieties, stimulates growth of weeds and increases weed competition. Nitrogen and other fertilizers applied during the early growing season enhance weed growth to increase yield losses. The time for transplanting younger rice seedlings from seedbeds to the field and the practice of direct-seeding rice intensifies problems with weeds because competition begins earlier in the life of the rice plants.

Changing patterns in crop production, which include use of crop rotation and multiple cropping systems, intensify herbicide residue and weed problems in rice and other crops throughout the region and a more intensive research effort will be required.

Hand weeding and cultivation are the principle methods of weed control in Southeast Asia whereas herbicides are being used extensively in plantation crops with high cash value. The rice acreage treated with herbicides varies from country to country, but is usually estimated to be less than 10% of the crop. Upland food, feed, and forage crops are seldom treated with herbicides. Plantation crops such as sugarcane, pineapple, rubber, and oil palms are frequently treated with herbicides; these crops, however, enjoy the attention of government and the private sector because they are exported. As more emphasis is placed on food and feed crops and as more industry develops, weed control programs in these crops will become more important. Because the cost of labor for hand weeding has recently increased in Taiwan, the use of herbicides increased from practically none in 1965 to about 60,000 ha in 1971 (5% of total), and this is indicative of the observed worldwide trend.

Although surveys of weed species in rice and plantation crops have been made in the countries visited, information is lacking on weed species in newly introduced upland food and feed crops.

Experiments on rice by the International Rice Research Institute (IRRI) and the University of Philippines College of Agriculture (UPCA) and in plantation crops by other research organizations have shown that weeds reduce yields and quality of crops. Similar information should be obtained on rice and other crops in all the countries because information from weed competition studies conducted in temperate areas often is not applicable to the tropics due to differences in the growth of weeds and crops in the diverse environments. Development of information on economic thresholds for specific weed-crop complexes will be essential in acquiring support for research and extension.

Many experiments on the evaluation of new herbicides for rice were observed, herbicide testing programs were inadequate in other crops. For example, Eupatorium spp., which is a troublesome weed

in pasture crops in the Philippines, has not been researched at all. Aquatic weeds, which are abundant in tropical climates, have drawn little, if any, attention from weed scientists. Research on the biology of important weed species and in the evaluation of control methods including cultural, mechanical, chemical, and biological practices should improve weed control programs.

Ecological shifts of weed species were noted where herbicides had been used continuously for several years. Rottboellia exaltata L.f. has become a problem in corn and sorghum subsequent to atrazine use. Scirpus juncoides has developed significantly in rice plots where herbicides were used to control susceptible weeds. Because herbicides are not used widely in tropical Southeast Asia such ecological shifts occur infrequently. Research to study (1) the shifts of weed species with continual use of herbicides and (2) the effects of herbicide and crop rotation should prevent or delay problems before they occur widely.

In all countries visited weed research and extension personnel, with few exceptions, were inadequately trained in weed research. Many scientists were working only part time in weed science, and frequently they were trained in plant breeding, plant pathology, nematology, or another discipline. A few weed scientists, who had been trained in the United States or in Europe, did not have an adequate understanding of weed problems in the field. In addition the limited weed resource personnel available were frequently devoting most of their time to teaching rather than research. When research was conducted it was often not adaptive field research which was the greatest need.

Frequently weed scientists located at field research and improvement stations away from university campuses did not have access to weed science literature and reference materials. Therefore, they could not develop effective weed research objectives and programs. Duplication of research efforts could become a problem as weed research is increased in Southeast Asia.

F. Middle East

Afghanistan
Iran
Pakistan
Turkey

1. GENERAL

In each of the countries visited, weed science was a secondary effort conducted primarily by people trained in another area of agricultural science. The work underway was often a herbicide testing program and invariably emphasized solving problems

which had been only vaguely defined. Weed science programs should be initiated or redirected toward problem definition. Specific programs which should be included are:

1. The identification of problem weed species by crop and region.
2. Weed competition studies to show:
   a) the density of a particular weed species or weed complex that causes economic loss;
   b) the critical time(s) of weed competition during the crop season;
   c) the yield reduction in weedy vs. weed-free stands.

Herbicides offer certain advantages to the farmer, but the size of farms, education of farmers, lack of application equipment, and an abundance of labor all argue against their widespread application at this time. For the near future, herbicide development should emphasize crop and human safety more than broad range phytotoxicity. After the weed problems have been adequately defined and other yield improvement inputs reach a level where weeds become limiting, herbicides should be judiciously employed as a tool in the quest for higher agricultural production.

All four countries need research workers, at all levels, specifically trained in weed science.

2. AFGHANISTAN

There is no program of weed research in Afghanistan. No herbicides are commercially available, but two companies have imported small amounts for demonstration purposes. There is no course in weed science, nor is it included in any other course at Kabul University. No one at the University or in the Ministry of Agriculture has received specific training in weed science. The Agronomy Department at the University has started a weed herbarium but little identification has been done because of the lack of taxonomic assistance.

Visits to the Kabul, Jalalabad, Kandahar, and Lashkar-gah areas revealed serious weed infestations in all crops. As yields rise and the inputs of fertilizer, improved varieties, water management, etc., are made, weeds will become more important factors in yield reduction. A survey of major weed problems, by crop, and expansion of the poorly developed University weed herbarium should be accomplished in the near future. Demonstration studies of the effect of weed competition on yields would help to pave the way for the introduction of weed control by hand or cultural methods. Chemical control should be introduced but only slowly in crops such as wheat, that are difficult to weed by hand.

The weed control problem is complicated by the fact that weeds are generally regarded as by-products of agriculture and not as deterrents to yield. Weeds are viewed as either livestock feed or

fuel. Even camelthorn (Alhagi camelorum Fisch.), an unpalatable plant by most standards, is eaten by camels. Thus, an intensive extension effort is needed to convince the farmer that crops are more valuable feed than weeds, that higher yields can be produced with lower weed populations, and perhaps even that fuel could be purchased with income from the sale of higher yields.

The programs recommended will first require that those in positions of authority at the Ministry of Agriculture and the University recognize the problems of weeds and commit themselves to work toward solving them. Secondly, people must be trained in weed research and basic agricultural extension to do the adaptive research and education that will be required.

3. IRAN

Compared to plant pathology or entomology, the study of weed control is limited in Iran. Herbicides are used to a limited extent in rice and cotton in northern Iran and 2,4-D is used on wheat.

The major use of herbicides is in the Khuzestan region of southern Iran. Research on new herbicides and herbicide combinations in this area is comparable to weed control research in other sugarcane producing areas of the world. The project is adequately equipped and staffed. Two of the three agro-industry firms were contacted and they recognized weeds as a major problem. The control methods available to them are inadequate. The firms employ hand labor for weeding and other purposes. The question of the displacement of this labor by herbicides was discussed and found to be a sensitive issue. The firms are emphatic in their belief, that herbicide use will be essential to their continued progress. They recognize the problems this could create but state that the labor supply is presently inadequate, and will become more so as their operations grow. No other statements were obtained from other sectors on this problem but the inevitability of the change is apparent.

The Safiabad field research station in the Khuzestan, is not adequately staffed to answer the difficult questions exemplified by the agro-industry operations. A Development and Resources Company (D&R) consultant in weed science is on the staff. Field help is available. As the D&R role is phased out the present staff is too small and not well enough trained to conduct the required research. D&R recognizes this and is actively working to rectify the situation.

A book "Weeds and Weed Control at the Haft Tappeh Cane Sugar Project" includes 74 species from 31 families. These represent problems in sugarcane culture and include the major weeds of the area.

4. PAKISTAN

Small scale herbicide testing programs were underway at the two provincial agricultural research institutes visited. No good weed control research was found with the exception of a program on rice conducted by Ciba-Geigy Co. Agricultural and plant protection research are largely the responsibility of the provincial agricultural research institutes and their substations. Their limited herbicide testing programs, which alone do not constitute good weed science programs, and the total lack of trained weed scientists and the requisite equipment explicitly exhibit the very low priority assigned to weed science. Even this very brief survey showed that the weed problems are serious enough and yield losses great enough to justify more research. The weed problem will soon become a more noticeable limiting factor in the production of crops. The present level of research is not adequate to cope with the problem and develop the solutions the future will demand.

5. TURKEY

With the exception of the USAID project on weed control in wheat, nearly all of the weed control research in Turkey is being conducted at the plant protection directorate's regional research institutes. At these institutes Turkey, like most other countries of the world, gives far more emphasis to other aspects of plant protection than to weed science. Most of the research now underway is conducted as an herbicide testing project, thus creating a great deal of emphasis on the use of herbicides to solve weed problems. Herbicides may prove to be the best solution in many cases but few examples of research on weed physiology, ecology, competition, and control by cultural or mechanical means were found.

Most of the people working on weed control within the government and universities have been trained as plant pathologists. There are a few people in the private sector with training in weed science. Those engaged in weed control were aware of many important weed problems but the research underway must become broader in scope and oriented toward solving a weed problem rather than merely testing one or two herbicides. To broaden their appreciation of weed control and their knowledge of weed science, Turkish workers should have a greater opportunity to discuss weed problems and solutions at the national level. Some attend the annual research meeting of the Plant Protection Directorate in Ankara, but we question whether there is adequate opportunity for weed science discussions between all concerned sectors.

The Plant Protection Department of the Faculty of Agriculture at Ankara University will offer a course in Weed Science in 1972-73. This will be the first and only course in the country. There is no one in the university system who has had specific training in weed science.

There is a conspicuous absence and even unawareness of the literature of weed science. The best resources were individual collections but library collections of textbooks were meagre and old, and journal collections were even poorer.

The use of herbicides to displace hand labor for weeding crops was discussed extensively. The opinion of the Plant Protection Directorate was that it recognizes this possibility but as agriculture modernizes, it considers the displacement of labor to be inevitable and is not overly concerned. Herbicides now represent only 7.5% of the total pesticide sales but the private sector expects this to grow. Herbicide use will probably expand most rapidly in corn, cotton, and sugarbeets, all of which are major crops. Migrant hand labor is now used extensively in cotton and sugarbeets and is becoming more expensive each year. Hand labor is still the most economical method for most growers. None of the plant protection institutes was studying the economics of weed control by various means.

III. SPECIFIC WEED PROBLEMS - A SUMMARY

Two kinds of problems were recognized in weed control: those derived from a temporary lack of knowledge (a new weed or one not previously studied) and those derived from a failure to recognize weed problems and an inability to progress toward a proper solution. Although the primary purpose of this 32 country survey was not to identify specific weed problems; to assist all weed scientists who are, or may be working in developing countries, a summary of the most often mentioned weed problems is included.

The six original reports mention 179 weed species. Those most frequently mentioned as troublesome are included in Table 1.

Table 1

WEED SPECIES MOST FREQUENTLY MENTIONED

Weed Species	Number of Countries mentioning weed as an important problem						
	Mediter-ranean	Central Africa	Central America	South America	S. E. Asia	Middle East	Total[1] Countries
Amaranthus spp.	5	1		5	4		15
Convolvulus spp.	5			5		4	14
*Cynodon dactylon (L.) Pers.	5	1	6	5		4	21
Cyperus (Primary species): Esculentus L. } *Rotundus L. }	5	8	6	5	4	4	32
Digitaria spp.	5	3		5	4	3	20
Eichinochloa *Crus-galli (L.) Beauv. } *Colonum (L.) Link }	5	1	6	4	4	4	24
*Eleusine indica (L.) Gaertn		1	6	5	4		16
Euphorbia spp.	1	1	6	5	1	2	16
Portulaca spp.	5	1		5		4	15
Paspalum spp.	1	6	5	5	1	1	19
Rottboellia exaltata L.f.		3	6	3	1		13

[1] Thirty two countries are included in this report.

* See Holm, L. Weed Problems in Developing Countries. Weed Science 17:113. 1969.

In some areas certain weeds were very important problems. Sorghum halepense (L.) Pers. was important throughout the four middle eastern countries and in parts of the Mediterranean and South America. Striga spp. (principally hermontheca) was important in all eight countries of central Africa but was hardly mentioned elsewhere. Imperata cylindrica (L.) Beauv. was a problem in South East Asia, Pakistan, and South America but not serious elsewhere. Other examples could be cited and a survey with the express purpose of determining which species were most important in terms of population and economic loss would be more precise than the data in Table 1. Nevertheless, the authors think Table 1 is indicative of the most important world weed problems. It is interesting to note that five of the weeds (indicated by an asterisk) in Table 1 are included in Holm's list of the world's worst weeds (Weed Science 17:113. 1969.) as are Sorghum halepense and Imperata cylindrica.

IV. SUMMARY AND RECOMMENDATIONS

Even a cursory review of this document will reveal several threads of consistency in the observations made by each author. The most consistent observation was that the weed problem is ubiquitous and serious. Indeed, it is more serious than is generally recognized and the enormous task is the most striking impression shared by the authors. Therefore, our foremost recommendation is that each country take immediate steps to initiate or strengthen programs in weed science. Without good programs of adaptive weed control research developing countries will be late in this portion of their agricultural development and the entire program will suffer.

In addition to this primary recommendation, the following recommendations are offered:

1. Definition of research needs and goals

There is a general recognition in the developed countries that weed control research efforts have not adequately defined the problems, assessed the losses and their importance, or demonstrated the relative value of available solutions. This deficiency is more obvious in the developing countries. Too often, if work was being performed, it was without a prior definition of the importance of the problem or an evaluation of the most appropriate solutions. Thus, herbicide testing was often the method of choice without adequate consideration of other methods. The importance of chemical control of weeds is widely recognized. The question is not, will herbicides become a major factor in crop protection in these countries. The question is when, how rapidly, and with how much good preparatory research will it occur. However, too much effort was spent on

herbicides at the expense of work on other control measures. Chemical control is often very expensive and foreign exchange shortages make purchase of some herbicides difficult or impossible. Some herbicides may be too toxic or have too narrow a margin of crop tolerance to be applied by poorly equipped, uneducated workers. At our present level of knowledge, adequate control of some important weeds, i.e. some perennial grasses, can be achieved only by chemicals. In comparison to most other control measures, the research involved in finding a chemical control is inexpensive and can be carried out in a relatively short time. Herbicides are thus suited to cope with emergency situations. Other methods such as cultivation, rotational practices, water management in rice, and sanitation have a number of advantages in developing countries. They are usually less expensive and safer than herbicides and provide opportunity for employment of agricultural workers.

The kind of research that is needed is adaptive or applied research. This is defined as research, which seeks effective solutions to urgent and pressing problems as distinguished from basic research whose objective is knowledge for its own sake.

2. Agricultural scientists must be encouraged to remain in research and teaching

The morale of agricultural scientists in many countries was low and they often felt their work was considered unimportant by society at large. This was especially apparent among the weed scientists. The state of low morale was made apparent by comments about working conditions and low salaries, and by attitudes toward their work in general. Everything possible should be done to increase the morale of agricultural scientists so they will want to remain in their professions and increase their productivity.

Because agriculture is the present economic base of many developing countries and supplies most of the foreign exchange, governments should take steps to insure an adequate supply of well educated and highly motivated scientists in teaching and research. Some actions that could be taken are:

a) Salaries should reflect the importance of the work. Scientists were generally found to be underpaid. Taxi drivers and hotel bellhops were often cited as better paying positions. It seems unsound for any society to expend thousands of dollars to train a man as a scientist and then employ him at a salary as low as that earned by an unskilled laborer.

b) The public relations activities of agriculture should be increased to make the general public more aware of the value of agriculture to society. Everyone honors medical doctors and the medical profession expends much effort in public relations. Few people are aware of the value of an agricultural research station and its staff.

c) Professional weed science societies and conferences should be encouraged and fostered in each country or contiguous area. Such activities provide a vehicle for broad relationships with government and related groups. They also provide for exchange of ideas and information among scientists, which is basic for progress in science, and serve as a forum wherein weed science programs can be debated and coordinated. Such coordination was noticeably lacking.

d) Publication of research results should be encouraged. New data are continually needed and the scientist needs the recognition that publication brings. Authorship of papers must be restricted to those researchers who have actually done the work. Too often a principal investigator has been relegated to junior author status by directors, department heads, or other administrators.

e) Refresher-type study programs should be instituted in each country by existing institutions or inovative aid programs. Science develops rapidly and if scientists are to remain properly trained they must be given opportunity to be brought up to date periodically. Every country has programs for the initial training of scientists but little provision has been made to keep them highly trained. Study leave programs should be so organized that working scientists are given the opportunities; leaves for administrators should be separate programs.

In many developing countries adequate capabilities now exist to train plant protection scientists and middle-level technicians. Some candidates for the M.S. and nearly all Ph.D. degree candidates in weed science should be sent for course work to a U.S. or other developed country institution. However, the student should return to his home country for his thesis research which can then be oriented toward applied research problems.

3. Reference literature availability must be improved

Most of the countries lack journal reference materials which are a vital part of an effective weed science program. With very few exceptions, the problem was present regardless of the type of institution. A few institutions in some countries had adequate libraries but they were exceptions and access was, of necessity, restricted to those close by. Part of the problem is that most of the weed science literature is published in English, which all workers cannot read. However, total unavailability is the more important aspect of the problem. The situation will worsen as journals proliferate and increase in cost. Some suggestions to alleviate the problem are:

a) "Current Contents" (reproduction of the title page of the principal plant protection journals) approach. A current contents publication on plant protection could be initiated by USAID or by

another agency such as a commercial publishing house. The publication might be sold in the U.S. and made available by USAID to selected research centers in developing countries. Any reader could request reprints directly from authors whose addresses would appear in each issue.

b) Journal article reproduction service. A center could be established at a university in the U.S. which presently receives the major plant protection journals. This center would serve as a central address for requests from research workers in all developing countries. Articles would be copied from the journal and mailed to the research worker at minimal or no cost. This option assumes that the research workers know of the existence of the published work through abstract journals or other sources and that copyright privileges will not be violated.

This approach bears some resemblance to the East African Scientific and Technical Literature Service located at EAAFRO, Nairobi, Kenya, which was described in the East Asian Pest Management Study Team report. However, most libraries in developing countries are not presently adequate to the task.

The second aspect of the reference problem is the dearth of weed science textbooks. Some private collections are present but for understandable reasons are not generally available. Two recommendations to alleviate this situation are:

a) A list of current textbooks be prepared and made available to institutions in developing countries. The list should include title, author, publisher, best source, and cost; and should be revised periodically as usage or availability changes.

b) All Weed Science Societies should be contacted and regularly informed of the need for textbooks and journals in the developing countries. Opportunities should be made available for retired research workers to sell, or give by will their personal libraries to the libraries of institutions of higher learning or research centers in developing countries. We think it important that such collections should be housed in institutions rather than with individuals.

A third aspect of the reference problem is the unavailability of abstracting journals in the developing countries.

4. Attention must be given to the lack of necessary equipment and the presence of inoperative equipment

In many of the plant protection laboratories visited, as much as 90% of the laboratory equipment was inoperative because of broken or malfunctioning parts. In general, the original equipment appeared to be of good quality and had been purchased recently. Although some of the inoperative equipment is highly complicated and sophisticated, the vast majority is standard equipment used regularly in laboratories throughout the world. The same situation was found to exist with equipment for field application of liquid and granular herbicides.

Some factors which contribute to this serious situation are: a) scarcity or unavailability of spare parts in many countries, b) inability to purchase many spare parts from abroad because of scarcity of foreign exchange, c) lengthy and complicated procedures involved in ordering spare parts from abroad, d) scarcity of trained technicians to install and repair equipment, and e) isolated locations of many researchers thus making it difficult to locate the spare parts and difficult or impossible for a maintenance technician to travel to the site.

It would aid this situation if only a very few brands of a particular kind of equipment were used in a country. However, equipment is usually supplied by a number of donor agencies and usually is manufactured in the donor country. More effective use of donor funds would result if USAID and other agencies would spend part of the funds now being used for purchasing new equipment to facilitate the maintenance of existing equipment and the purchase of spare parts.

One possible way to do this would be by training and helping pay the salary of maintenance technicians in the developing countries. Of course, ways must be found to supply these technicians with spare parts. One solution might be to establish a regional center which would supply spare parts and prepare and disseminate maintenance instructions in the language of each country or region. There is no easy and simple solution to this problem; however, the magnitude and importance of it requires that new and imaginative solutions be attempted.

5. Other comments

a) The need for order to be created out of the often chaotic and haphazard registration and labeling procedures for all pesticides. The systems ranged from the quite sophisticated to none. The latter serves as a serious deterrent to the development of the private sector and may jeopardize the development of agriculture in the country.

b) Plant quarantine regulations as they relate to noxious weeds and weed seed are in a similar state of disarray.

c) A major problem in many countries was the lack of adequate extension agencies to disseminate and encourage the use of research information. Most countries are aware of this deficiency and moving to overcome it.

In closing we again refer to Dr. Holm[2] who has prepared world maps on which he has shown the areas of the world with advanced weed control methods, the broad beginnings of weed control, and no modern weed control techniques. It is significant to note that all 32 of the countries included in this report are excluded from the group with advanced methods. Only a few of the countries have what Dr. Holm terms a broad beginning. It is these countries and their people to whom this report is dedicated in the hope that together we can contribute to the necessary solutions.

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[2] Ibid

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