COMMUNICATION of WEED SCIENCE TECHNOLOGIES in DEVELOPING COUNTRIES

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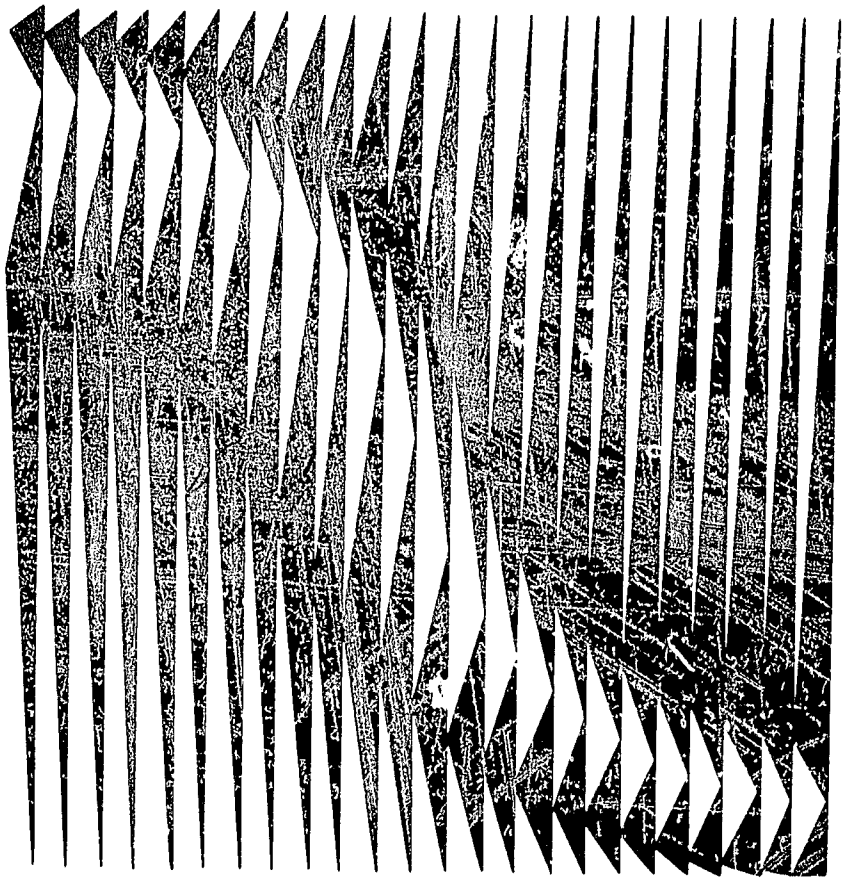
Shooichi Matsunaka
Robert D. Williams
Symposium Co-chairmen



COMMUNICATION OF WEED SCIENCE TECHNOLOGIES IN DEVELOPING COUNTRIES

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INTRODUCTION

Those attending this symposium had the privilege of listening to no less than 15 papers concerned with the requirements, problems, and achievements of weed science in developing countries: a fascinating pageant of personal experiences, analyses, theories, successes, and disappointments. Whilst difficulties predominated, a great deal was said which gave hope and encouragement for the future. Above all, the audience should have been left in no doubt about the vital role that improved weed control practices can and must play in helping farmers and their families in developing countries to grow more food and to improve their standard of living and their health.

The span of subject matter covered by the papers in these proceedings is wider than the theme implied by the symposium title, which literally means the transfer of weed science technologies <u>within</u> or <u>between</u> developing countries. Communications was a key word throughout the program and it was used in a general sense by many contributors. Others, whilst addressing themselves to the actual transfer of improved weed control technology, did so largely in the context of transfer from developed to developing nations. It is clear, therefore, that we are here concerned with the whole broad scenario of how to promote

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1/ A personal synthesis based on papers presented at the IWSS-WSSA Symposium on Communication of Weed Science Technologies in Developing Countries.

weed science and technology in developing countries as an essential part of efforts to grow more food and increase wealth.

As an introduction to this volume and in attempt to draw some conclusions from the symposium, I have selected a number of issues which featured often and in various forms. I have given them a wider perspective and discuss them here briefly as topics which deserve further attention and action. In particular, I have highlighted the crucial roles to be played by FAO, the CGIAR network, IWSS, and the national and regional weed science societies.

COMMUNICATIONS AND TECHNOLOGY TRANSFER WITHIN A COUNTRY

Since the primary purpose of weed research is to improve the efficiency of agriculture, there have to be strong and effective links between the weed scientist and a wide range of individuals and organizations concerned with the agricultural system of his or her own country. This may seem obvious, but isolation of weed researchers, particularly those in universities, is by no means uncommon. The problem is referred to in several papers as are the many difficulties involved. In Fig. 1, I have attempted to summarize the communication network at national level in which weed scientists are likely to have to operate.

Extension personnel. In presenting the future, I have attempted to indicate that information flow can and often should be in many directions. The weed scientist is quite likely, for example, to be the main source of information about weed control and weed behavior for the extension officer specialists from industry, who are often highly skilled in helping farmers and estates to adopt improved weed control practices. The paper by Elster provides a good example of their expertise.

Administrators and the public. All of us attending this symposium are aware that ignorance and indifference by agricultural and scientific administrators are often at the root of inadequately supported weed research throughout the world. But how many weed scientists who complain about the lack of support they receive really put much effort into trying to improve the situation? Two comments in the papers we have heard particularly caught my attention. One was

by Vernon who describes how an article entitled 'The Expensive Weed' he wrote for a local farming magazine was picked up by the main daily newspaper in Zambia and led, through the national coverage it received, to a change of attitude within the Ministry of Agriculture and to greatly improved support for weed control work thereafter. The other was by Fischer and Vernon who so rightly pointed out that however adverse circumstances may be in a country, that despite indifference, bad leadership and lack of support, a weed scientist who has the strength of character and the enthusiasm will always be able to make headway. I strongly agree with them that these are the people who most deserve our support.

These authors endorse the need to make the government officials aware of the importance of weed research and I am glad they, also Fischer in his own paper, refer to the great help that has been given in this and other respects by the Mexican Weed Science Society. This is an extremely important function of such societies. As I noted in my paper at the Weed Science Society of America (WSSA) special meeting at Dallas in 1978, the formation in the UK of the British Weed Control Conference in 1953 played a vital role in securing greater government support for weed research and without which it is unlikely that Weed Research Organization (WRO) would have come into existence.

In a wider vein, Nicholson refers in his paper to the need for a broader segment of society to be interested in and knowledgeable about agriculture to help generate and maintain support for agricultural research as a whole. This is an important point and a highly topical one in view of the growing disenchantment with government support for agriculture in Europe and North America caused by mounting food surpluses and problems associated with intensive production methods.

Weed scientists. Having referred to my institute prompts me to endorse the need highlighted by Fischer and Vernon for weed scientists to communicate not only with the network of organizations in Fig. 1, but also with each other. In a large country (or even in a small one where weed research is undertaken at a number of universities, government institutes, and perhaps private research centers) it is all too easy for workers to become isolated and their research

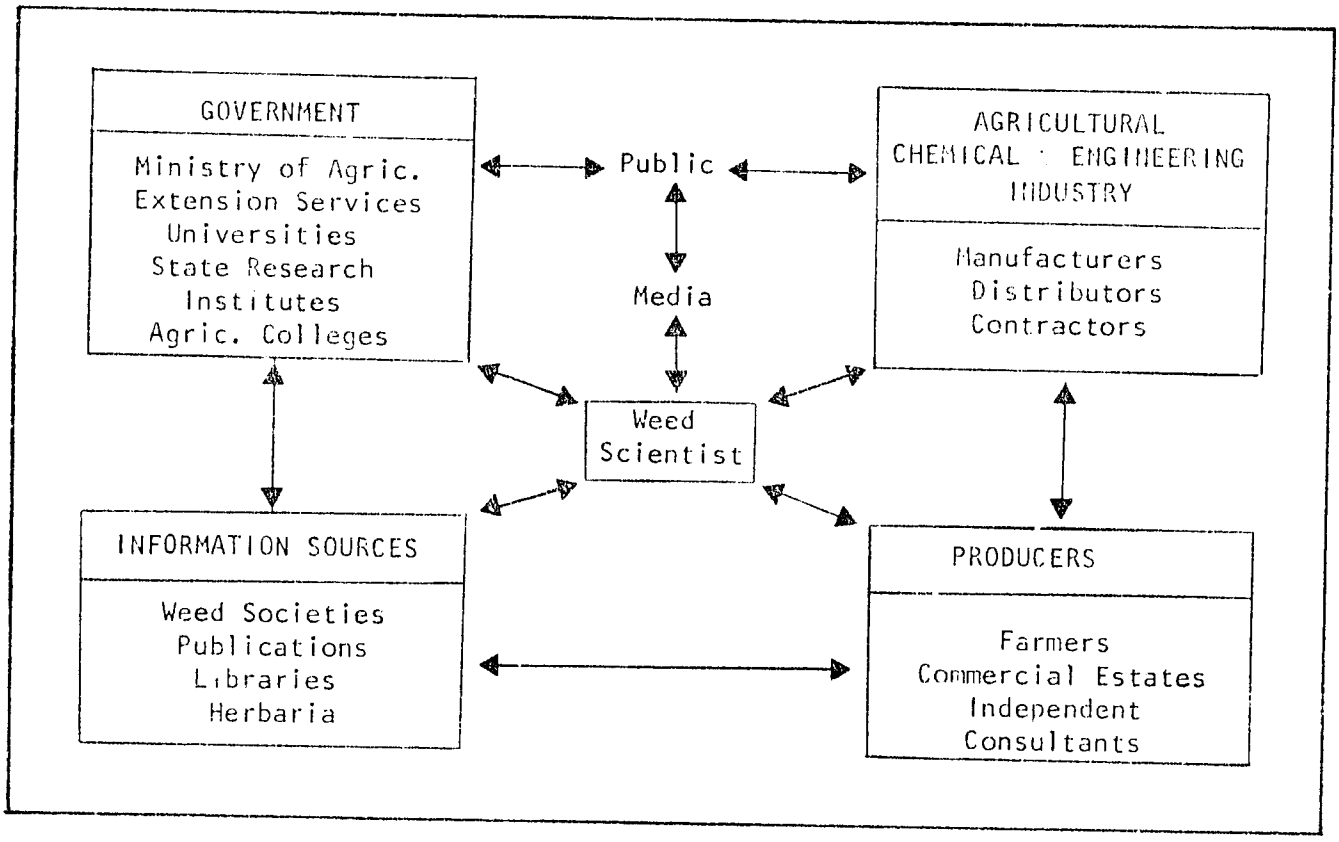

Figure 1. The agricultural communication network within a developing country.

to be poorly (if at all) co-ordinated. At WRO we spend a great deal of time in informal liaison and co-ordination activities to encourage weed scientists and others with whom they should interact to get together. This role is much appreciated and has certainly helped to promote enthusiasm and support for our discipline as well as more effective national programs of all sorts.

Trainers and trainees. Another activity undertaken by WRO in addition to our primary research function is the provision of periodic training courses, usually one-day affairs, but occasionally lasting up to two weeks. The need for such courses in developing countries is of course paramount, and Nishimoto has given us an interesting account of some in which he has participated. At WRO we are fortunate in having some 50 graduate weed scientists, so we are able to cover a wide range of topics unaided. In countries where weed science is less well supported, it may be essential for specialists from overseas to be brought in to help. Wherever possible, staff of local universities should be encouraged to participate in relevant courses as instructors or trainees as appropriate.

The lack of university departments teaching weed science is noted by several contributors as being a major deterrent to the advance of this discipline in developing countries. Such involvement can help to generate interest, as well as an awareness of the economic and social importance of weeds and weed research. The dearth of universities providing specialist courses in weed science is not of course restricted to developing countries.

Constraints in technology transfer. Turning for a moment from communication to technology transfer at national level, I should like to refer briefly to the interesting papers by Freeman, Johnston, and Nicholson which contribute the important socio-economic and philosophical elements to this debate. Freeman has provided us with a helpful analytical approach towards the determination of the underlying motivation for the adoption or rejection of improved weed control technology. It is all too common for research workers to be blissfully unaware that the solution to a problem they are so earnestly investigating has little chance of being put into practice on account of lack of incentive or other constraints as both Freeman and Nicholson describe so well in the context of developing countries.

Johnston quite rightly emphasises the risk that the introduction of herbicides may displace labour where jobs in rural areas are scarce, thus contributing to unemployment. He concludes that in such areas the use of labour-intensive weeding methods is greatly to be preferred, quoting the use of hand-pulled rotary weeders in rice. He makes what to some may be a surprising point that adoption of more efficient weed management techniques can actually lead to an increase in labour inputs per acre through enhancing the productivity of a cropping system and hence the wealth of farmers. This applies of course not just to hand and mechanical methods, but equally to intergrated weed management systems involving herbicides. A well-known example is the increase in labour used for hand-weeding rice in the Philippines following the introduction of 2,4-D as a supplement to hand-weeding. It can hardly be over-emphasised that in small scale farming in the tropics, hand-weeding, cultural methods of weed control, and herbicides can all work together to the benefit of rural communities. They should not be regarded as mutually exclusive.

One other comment is needed on this contribution. Even where there is normally abundant labour, it is common in many farming systems for there to be such drastic seasonal requirements for work in sowing or harvesting crops or tilling the land that serious bottlenecks occur and there simply is not enough time to hand-weed the crops effectively in addition to all the other jobs that must be done. Moreover, there are many weed control problems for which neither hand nor mechanical methods are satisfactory: hoes do not function effectively in wet weather, soil conditions may not allow tillage, many perennial weeds cannot be eradicated by handwork; repeated cultivation for weed control may cause disturbance of crop roots and water loss leading to reduce yields. Examples can be found in the papers by Li Yang-Han, and Fischer and Vernon. In such situations the use of herbicides, in association with manual methods, may be the only way to achieve the high level of weed control needed for maximum crop production. Moreover, their unique ability to kill weeds without disturbing the soil can allow revolutionary changes in farming methods to be practiced with great benefit, a good example being minimum or zero tillage cropping systems.

COMMUNICATION AND TECHNOLOGY TRANSFER BETWEEN NATIONS

What can be done by the more advanced nations to help promote weed science in developing countries and to assist their weed scientists? Some of the many organizations and their relationships are shown in Fig. 2. Reading through the written papers for the symposium, supported by my own experience, I have selected three topics for brief discussion: training, literature, information and advice.

Training

Matching courses to students and vice-versa. The successful transfer of any kind of technology is dependent on appropriate training being available to all concerned. At least five of the papers in this symposium draw attention to the

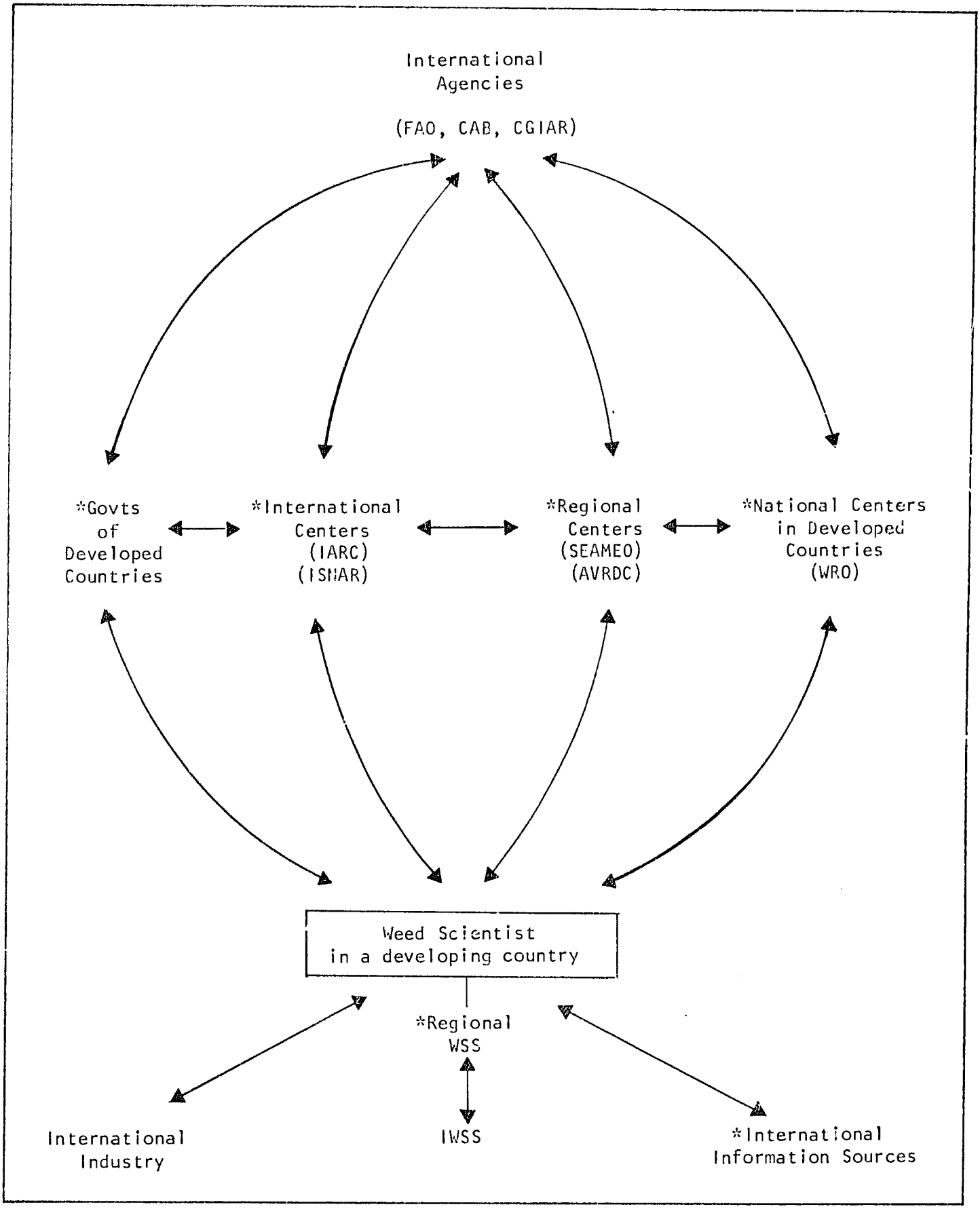

Figure 2. Organizations concerned in the communication and transfer of technology between nations (*see appendix for examples).

crucial requirement for training weed scientists in developing countries and emphasise the importance of their own role in providing training for extension workers, farmers, and others in their countries. All authors stress the need to ensure that training courses are appropriate to the work the participants will have to do when they return to their jobs. Appleby and Sweet also stress that very careful selection must be made of candidates allowed to attend advanced long-term courses overseas. They point out that not only is time and money wasted if a student is not well matched for a particular course, but that actual harm can be done by an unsuitable student becoming demoralized during the course itself or worse still after he or she has returned home having failed to acquire the expected qualifications.

Higher degrees. The risk of the Ph.D. training not being matched to the research requirements of the student's country, or even resulting in the student deciding not to return home at all, has to be taken seriously. However, I doubt if anyone will dispute that the most able weed scientists, those identified as future leaders in their countries, are likely to benefit, together with their work, if given the chance to take higher degrees at institutions overseas where appropriate training is available.

I stress the word 'appropriate.' Ideally this type of training should combine a research project with formal course work aimed at providing a broad base of knowledge of agriculture, crop protection, and weed science. Courses of this nature include those available at the Department of Crop Science at Oregon State University in conjunction with International Plant Protection Center (IPPC), University of the Philippines, Los Banos, and Reading University (UK) in association with WRO. A valuable feature of some universities is that they provide for those students who, having undertaken the course of formal lectures, wish to complete their degree by carrying out their thesis research at an agricultural research center in their own or another developing country.

Special training courses. Several contributors point out that, for many weed scientists concerned with applied research and extension work, specialized training courses lasting for a few weeks up to a year are much more appropriate than a three-year Ph.D. study. It would be helpful if wider and formal recognition of this in academic and official circles could be achieved. The requirements of such courses are well set out in the paper by Nishimoto, who draws attention to the fact that this form of training enables participants themselves not only to become more proficient at their work, but to also become qualified to train others when they return home, thereby helping to extend the expertise available in their country. He also comments that courses should not be regarded as 'one-off' affairs and that participants should be offered the chance to attend refresher courses from time to time to enable them to catch up with recent developments. This of course is correct, but the practical difficulties of mounting such courses at regular intervals are considerable.

How to encourage the development of a network to cater for the training requirement of weed scientists in developing countries is a vitally important issue to which we should address our attention. What can be done and who can help?

FAO. The recent initiative of the Food and Agriculture Organization (FAO), in conjunction with International Weed Science Society (IWSS), which led to a review in Rome last year of the need for weed management training in Africa,

is encouraging, particularly as there are plans within the framework of the FAO/UNDP Action Program for Improved Plant Protection to sponsor a series of short courses in a number of countries there. I hope this will pave the way to a similar activity by FAO in other countries.

International Agricultural Research Centers. The helpful role of the International Maize and Wheat Improvement Center (CIMMYT) in training weed scientists in agronomic matters in Mexico is acknowledged by Fischer in his paper, and the active weed science programs at the International Rice Research Institute (IRRI), and the International Institute of Tropical Agriculture (IITA) are well known.[2/] These and the three IARC's would seem to be well placed to serve as keystones for an international network for training centers for weed scientists concerned with agriculture in developing countries.

ISNAR. The International Service for National Agricultural Research was established with support from Consultative Group for International Agricultural Research (CGIAR) in 1980. Its primary mandate is 'to help strengthen national agricultural research capabilities in developing countries', with the aim being to complement other sources of technical assistance. Training is seen as one of the most important ways progress can be achieved, and its intentions, as set out in the ISNAR brochure, are admirable. These include the organization of symposia, workshops, seminars, and training programs for research managers and scientists from national institutions. It is essential that those who control ISNAR should be made fully aware of the vital role that weed science has to play in assisting the service to fulfill its primary role, namely 'ensuring that the benefits of improved technology are made widely available to increase global agricultural production.' FAO and IWSS have a clear responsibility to make sure this is done.

IWSS. IWSS, with much help from WSSA, has already made a good start in focusing attention on training requirements in developing countries by organizing this symposium. I hope, that in collaboration with FAO and all the regional weed

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2/ Other IARC's are provided in Appendix I.

science societies, it will continue to promote training courses at regional level as is already being planned for Africa. There are many other ways IWSS may be able to help. Here a few examples:

(1) preparation of a list, revised annual, of weed science training courses catering for students from developing countries;
(2) promotion of teaching aids and training manuals appropriate to different regions and in a range of languages, along the lines of those available or in preparation for the Philippines (B. Mercado), Australia (J. Swarbrick), and Indonesia (P. J. Terry). It is worth noting at this point that preparation of a directory of teaching material for weed science is currently under consideration by the Education Committee of the European Weed Science Society (EWRS); and
(3) serving as a clearing house for inquiries concerning the names and special expertise of weed science experts who may be available to participate in local training courses.

Regional Centers. The Southeast Asian Regional Center for Tropical Biology (BIOTROP) in Indonesia is, I believe, unique in having provided over many years a succession of excellent short and one-year training courses for weed scientists from throughout the region. There has been extensive use of expatriate weed specialists as instructors, particularly in the early stages, until adequate local expertise became available.

Regional and National Weed Science Societies. The interest, initiative, and cooperation of these bodies are essential if IWSS/FAO are to be fully effective. Moreover, each can play a positive role on its own in organizing local training courses. A recent development in EWRS has been the establishment of a Tropical Weeds Liaison Group to promote communication and liaison between individuals and institutes in Europe concerned with weed control in developing countries.

Literature, Information and Advice

Literature. Unfortunately, the depressing picture painted by Fischer and Vernon about the non-availability of agricultural publications in Zambia is typical of many developing countries. We should note their suggestion that this problem,

which is largely caused by lack of foreign currency, could be overcome if technical aid were to include the establishment of an investment trust fund in the donor's country; the annual interest from this would be used to purchase scientific publications for the recipient country. They also stress the importance of the technical publications which are widely distributed to developing countries without charge such as the IPPC Infoletter and Tropical Pest Management. The IWSS bibliography of key weed science publications is a valuable contribution, and I hope that support will be forth-coming to enable it to be continued and extended.

There certainly seems no easy answer to the problem of ensuring that weed scientists in developing countries have direct access to even a modest collection of essential literature. Fischer and Vernon consider that up-dated reviews covering particular areas of weed science would be of enormous benefit. It would be helpful if IWSS were to consider how the production and distribution of more of these might be promoted. The need to translate existing reviews into major languages also needs discussion. Another good point made by these authors is the importance of external sponsorship of key weed scientists in developing countries to allow them to attend major conferences abroad. Where this can be done there is often an opportunity for the weed scientist in question to purchase or be given textbooks and other publications which he can take back with him to his country. Moreover, the personal contacts which are made by attending conferences are of great importance in helping to overcome problems of isolation.

Reporting Research. The vital need for weed scientists in developing countries to report the results of their work, both to other weed scientists and to the agricultural community at large, is stressed by one or two of our contributors. The difficulties of communication however can be formidable: an unreliable or non-existent telephone service, lack of facilities or money for reproducing research reports, lack of local technical journals, ignorance of those international journals which might publish articles on weed science, the need to match up to the standard of texts required, and of course the language problem. Local and regional weed societies can help a lot here. By the organization of conferences with printed proceedings, or failing that, by regular publication of newsletters or research reports, opportunities can be provided for the results

of local endeavors in the weed science field to be made available to others who can benefit from them. If published regularly, such reports will increasingly become a part of library holdings in many countries and will also benefit authors by drawing attention to their work and by promoting contacts.

Specialist weed science journals. For reporting research of a suitable standard there are, of course, the specialist weed science journals. Examples are Weed Science, Weed Research, Weed Research, (Japan), Australian Weeds, and the weed science journals of the Philippines, India, Korea, and Taiwan. In the case of Weed Research, we are receiving an increasing number of manuscripts from workers in developing countries. This is an encouraging sign that serious research in weed science is on the increase and that there is a growing awareness of the benefits of publishing work in an international scientific journal of high repute. Unfortunately, many of the manuscripts submitted to Weed Research are concerned with work which is trivial in nature or has been poorly conceived or executed. There is no alternative but to reject these, albeit with regret if the author has made a real effort. Others report work which is inherently sound and worth publishing, but which is presented quite unsatisfactorily. In such cases, my colleagues on the editorial board, who between them cover a wide range of expertise in weed science, are prepared, quite voluntarily, to go to much trouble to help authors to upgrade their texts in order to achieve the required standard. Here then, is a source of skilled assistance and advice, given willingly and often in the editor's private time, to help weed scientists who are in need of guidance in the correct reporting of experimental work.

Sources of advice. This leads on to the need of advice generally at all levels of weed science. Again, here is a role for weed societies which I am sure many effectively play already. Even if officers of a national or regional society cannot answer the queries put to them by their members, they ought to be able to direct them to one or other of the many centers in various parts of the world which have major weed science programs, or failing that, they can turn to IWSS.

One of the main reasons for establishing an international society was to provide a back-up communication network for national and regional weed societies and, where these were not available, for individual weed scientists working anywhere in the world. For a nominal subscription, they can join IWSS and

benefit from the advice which is always generously available from the secretary at IPPC Oregon, or through the center's many contacts. These include: the International Agricultural Research Centers which can provide high level advice in many aspects of agronomy, agricultural science, and farming systems; specialist weed research centers such as WRO at Oxford, the Royal Tropical Institute at Amsterdam, and many centers in the United States; FAO and other technical assistance agencies, major agrochemical companies and their international trade association (GIFAP); regulatory bodies; major national crop research stations specializing in particular tropical crops; national and regional weed societies, universities; and government agencies concerned with food production in third world agriculture. All, and many others, can provide advice and help if only the right contacts can be made.

A Recent Set Back. At WRO we regularly receive requests for advice and information from weed scientists in developing countries. The wide range of expertise we are fortunate enough to possess, backed by worldwide contacts and probably the most comprehensive weed science library and information network available anywhere, has proved helpful over the years to weed specialists from many countries. The unique role of WRO was emphasised by delegates from developing countries who attended the FAO/IWSS Expert Consultative Meeting on Weed Management Strategies for the 1980's for the Less Developed Countries (LDC's) held in Rome last September. Regrettably, the funds we have obtained from the government for more than 30 years to help us fulfill this role were terminated in 1981 due to cuts in public spending. The institute's formal remit has, in consequence, become limited to assisting British agriculture. There now exists a real risk that in the future the role we can play helping weed scientists in developing countries may greatly diminish, unless our Ministry of Overseas Development or some other agency is willing to fund tropical weed science work at WRO.

CONCLUSIONS

It seems generally agreed that the gap between food availability in the third world and the ever-growing needs of the people who live there can only get wider and that the problems of hunger will not be solved by encouraging countries in more favored temperate areas to increase their current food

surpluses for distribution to the undernourished millions living in the tropics. There seems no disagreement that the way ahead must lie in helping the developing countries to increase their own food production by upgrading their indigenous agricultural systems. If this is to happen successfully, then it is absolutely imperative that weed control technology is also developed in these countries. Whilst hand-weeding, fire, and the hoe may have served their purpose reasonably well over many centuries of traditional agriculture, they will often fail totally in the context of intensified agriculture in the tropics, regardless of the number of human beings per square mile. If successful agricultural development is to take place in the pursuit of more food, weed science simply has to be better supported than it is now in most countries.

To communicate this fact forcibly--and with the necessary evidence--to scientists, administrators, and politicians, is the single most important and urgent task requiring our attention. How is it to be done? I believe all weed scientists have a role to play. We have heard how the initiative of a colleague in Zambia who wrote a popular article on loss of production of the national food crop caused by weeds led to recognition at government level of the need for weed research to be better supported. There must be countless opportunities for local weed scientists the world over to undertake surveys of crop losses by weeds, to write articles and, to mount demonstrations and exhibits which quantify and publicize the devastating impact of weeds and the inherent inadequacies of traditional methods of weed control for modern farming systems. They need encouragement and help.

Weed societies are already playing an important role. Can we assist them to do a better job? So often their effectiveness, even their existence, is governed by the availability of just one or two dedicated enthusiasts. These are the people who deserve our support. Do we know who they are and what help they need?

It is perhaps at the international level that there is the greatest need for the importance of weed science to become better understood. It is to FAO and the international centers to which one must turn for active support, goaded and aided by IWSS and the regional weed societies. It is heartening that the FAO/IWSS partnership mounted the very successful Expert Consultation in Rome

last September and is now sponsoring the training course initiative in Africa; also that FAO has, I understand, agreed in principle to the formation next autumn of a permanent panel of experts on weed management. It seems that at last the giant which has slept for so long as far as weed science is concerned, has awakened. Much credit must be given to L. Matthews of the FAO Secretariat for his efforts in this direction. The FAO/IWSS partnership must continue. The two organizations acting together can achieve much more than either on its own. It should not be overlooked that in the final analysis it is the attitude of national delegations from UN Member Nations attending key FAO meetings which really matter. It is they who dictate priorities and budgets. It is important that those of us in a position to do so should ensure that members of such delegations are properly briefed about the need for weed science to be appropriately supported in developing countries and the essential and very positive role that FAO has to play.

In conclusion, I should like to record my optimism that the crucial role of weed research and improved weed control technology in the more extensive systems of crop production so essential in developing countries to feed the growing populations is at last becoming accepted. If the momentum, now gathering, is to be maintained, progress must be made in achieving the many and varied requirements for communication and technology transfer identified during this symposium. WSSA and IWSS are to be congratulated on their initiative in arranging and sponsoring this meeting, which I believe has achieved much. Do not, however, let us disperse thinking that our task today has been completed. It is my view it is just beginning!

ACKNOWLEDGEMENT

I am greatful to my colleagues C. Parker and Mrs. Anita Wilson for their help in planning the text and preparation of the figures, respectively.

CONSTRAINTS OF RESEARCH AND THE TRANSFER OF TECHNOLOGY IN SOLVING HUNGER[1/]

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INTRODUCTION

The Carter Commission on World Hunger and Malnutrition (13) asserts that the United States is morally obligated to help solve the problems of world hunger and malnutrition, that it is in the long term interest of the United States to help conquer world hunger, and that the world's chronically hungry are hungry primarily because they are poor. That is, people are hungry because they have neither the income to purchase food nor the resources to produce it themselves.

If that is the case, then solving the problem of hunger is not only a matter of increasing the world's total supply of food. And research directed simply toward producing more food may never touch the lives of the hungry. There is no way to choose between production and equity. If research is to be helpful it must increase production with equity; research must be directed toward increasing the capacity of the hungry to survive. Production by itself

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1/ Portions of this paper were presented at the Church-University Conference on World Hunger. Yahara Center, Madison, Wisconsin. April 1981.

may never reach the poor, and equity by itself may mean that the poor share ever more meager resources.

Should agricultural scientists in the United States engage in research to alleviate hunger in other nations? The automatic response is YES! because the system of agricultural research in the U.S. is unparallelled in responding to the problems people face in growing and consuming food. It is a natural way for us to help because we are good at it, but especially because we can more readily afford to invest in research than can the governments of nations with severe problems of hunger and poverty.

What, then, is the role of research and what are the constraints on its effective use in combating hunger? The overarching constraint is that research by scientists in the United States can, at most, assist other people and nations in solving their own problems of hunger and poverty. We must be constantly aware that in international agricultural development the nations with which we deal are sovereign, independent states. As scientists we are prone to overlook, or at least not to understand, the political realities that affect the way we perform our science at home. If we also fail, in our dealings with other nations, to recognize the political and social realities peculiar to them, then we may never effectively assist them in the alleviation of hunger, regardless of our zeal.

With the purpose of designing an appropriate role for research, the first section of this paper challenges researchers to be more sensitive to the political and social constraints on technically elegant solutions to hunger. It also challenges the politically and socially sensitive to be more aware of the biological constraints on socially desirable solutions. In the application of technology, it is often a question of developing or adapting a procedure rather than exporting ready-made solutions. The second section examines the incentives and disincentives to genuinely helpful research. The final section addresses what I consider to be an overriding problem to the solution--the image of biological technology as the coming solution to hunger.

CONSTRAINTS ON RESEARCH

While the problems of hunger are global, the problems of producing food are unique to geographic areas and the patterns of choosing, preparing, and consuming food are firmly established in local cultures. Appropriate research must take account of the fact that people like and can grow different kinds of food. Foods which are standard in one community are socially unacceptable or physically indigestible in another. A program for adapting soybeans to new growing conditions as a protein supplement would be pointless if soybeans are unacceptable as a food.

Research which is culturally specific and sensitive must at some point involve the intended beneficiaries, since they are the experts on the changes in production methods and consumption which can be implemented. Just as social factors are specific to communities, biological and environmental factors which limit plant and animal production are specific to geographic areas. Temperature, average day length, soil fertility, and water availability obviously influence plant growth. These same factors influence the occurrence of specific disease, insect, and weed pests. The pests determine what plants and animals can be grown; they also reduce the yields, even of those which are best suited to that environment. Research which strains the ecological adaptability of plants and animals may result in frustrated farmers and more hunger.

Some areas of land are far better suited to agriculture than others. For very fragile areas, particularly in the tropics, there may be a direct conflict between the goals of the residents and the need to preserve the soil. A family may need to collect scarce wood as the only available source of fuel. The resulting deforestation has national impact on food production and global impact on the environment. Protecting the environment and conserving the soil may cost the residents their livelihood. In some areas research which leads to a more abundant source of fuel is as critical to survival as more food.

Patterns of land tenure often are more politically than environmentally determined and dramatically affect the kinds of research that can be implemented. A large share of current research by industrial and agrarian countries understandably is directed toward export crops, since these are a major source

of foreign exchange. Increased national income from research on export crops often does not reach the poor as increased family income. A politically realistic assessment is that research on export crops will have priority so long as the export crop is a major source of national income and strengthening a nation's economy hastens development. A biologically and environmentally realistic assessment is that, so long as the export crop accounts for a large land area, an investment in research is warranted. Many crops in agrarian nations, like most major crops in the industrial nations, are grown in monoculture. And monoculture of rice, coffee, and jute, like monoculture of corn and soybeans, requires research to keep ahead of biological stresses and to reduce environmental damage.

One of the problems of monoculture and the export crop is that it is a leader in the displacement of people from the land. Where most of the poor, even the rural poor, are landless, crop-related research may increase the gap between rich and poor, and worsen the problems of the chronically hungry. How are these people reached? Critics have argued that too much of the technical assistance offered by the industrial nations has stressed genetic similarity and large land areas as a means for increasing productivity. In many nations the poorest citizens either own small amounts of land or have access to land as tenants. To help these farmers, research must be directed toward the effective use of small land areas for food and income. Of equal importance to research is its practical implementation. Regardless of its quality, research will have no impact in the absence of a well structured, dependable extension or outreach program that stresses people working together. In many of the developing nations, those who advance to extension service positions are often from more wealthy and typically urban backgrounds with little understanding of the traditional practices of agriculture. It should come as no surprise that some farmers question the validity of outreach programs.

The established agricultural network of a nation affects the appropriateness of research in which scientists might cooperate. For example, agricultural research agencies in some nations are charged primarily with improving the trade position of export crops, possibly at the expense of food for local consumption. In other nations, the university system may serve inadvertently to maintain two cultures--the increasingly rich and the permanently poor--by investing in

sophisticated technology which may never "trickle down." It is also a reality that in development, industrialization is a more tempting route than improvement of the agricultural sector.

Governments differ in their commitment to solving problems of any description. Even a government genuinely committed to overcoming hunger must make concessions to powerful constitutuencies, often those who own extensive land, or focus on urban problems. The research scientist needs to be aware of political relationships in order to evaluate what inroads might be acceptable. Is basic research on a "poor people's crop" more acceptable than applied research or extension? Are informal ties to nongovernmental organizations more or less likely to reduce hunger than an official joint project?

If possible, the most stable levels of society should be included in research programs: the poorest farmers, village leaders, middle and lower level bureaucrats. Developing programs which include the more stable groups in society can help to insure that progress through research will survive changes in government. This may not be easy. For example, agricultural research institutions' involvement with farmers varies with the institution as well as with the nation. The complex network for dissemination of information and assistance found in the industrialized nations is simply nonexistent in the developing nations.

The international research centers are sometimes unfairly critized on the basis that they lack an adequate people-to-people approach. What few of us realize, however, is that the centers often are buffered from such contact by the existing national agricultural research network. The centers exist at the discretion of their host countries and are responsible to the political structure of those countries. To be effective at the farmer level, the international centers must work through the national agricultural system. From the perspective of the host country, the center may be only a temporary aid to developing a strong and stable agricultural research service.

These are just a few of the constraints researchers face if they would direct their efforts toward eliminating hunger. This perspective is essential

to the extent that we enter the research process realistically and without dampening our enthusiasm. Investing in research without first understanding the constraints is a waste of time, money, effort, political resources, and leverage. How then do we encourage the assistance of the research community?

INCENTIVES FOR RESEARCHERS

One form of cooperation in international research which will continue to be important is having students from other countries come to the United States to study. Many American scientists participate by accepting students, since it takes little extra incentive. The students often arrive with adequate stipends, and more than adequate ability, preparation, and commitment to learning. The problem of incentives is not only for the American host, but also for the visiting student or scientist. Often, programs are not carefully designed to address the problems the returning scientist will face at home. Students are often trained in methods of science which depend upon technologies in the laboratory and the field which simply are not available. Yet learning to employ sound scientific methods does not require the use of sophisticated hardware. In effect, visiting students are socialized into the western culture of science and may no longer fit into the scientific culture in their own country. They are caught between desiring to remain here to do the kind of science they have been trained to do, or returning home with an inappropriate background for solving challenging problems.

Many more forms of cooperation are appropriate. Masters and Ph.D. programs can be better designed if we are more sensitive to the political, social, and agricultural constraints discussed in the first section. Programs should be based upon mutual understanding of the scientific culture in which the student will be practicing. If the home nation cannot provide adequate incentive for the student to return, then perhaps we should. Certainly one incentive could be the development of cooperative research programs which would extend back to the student's country after his or her return.

Currently, there are few opportunities for agriculturalists of developing countries to study in the United States unless they are pursuing formal degrees such as the Ph.D. Not everyone needs an advanced degree. Short term associate

degree programs may be a partial answer, but such degrees must be viewed as legitimate and not as runner-up to the M.S. and Ph.D. Arrangements which will allow extension agents, agricultural technicians, students, and university faculty to come here for short term attention to a particular problem need to be developed. Certainly workshops in crop protection and related subjects need to be expanded to provide opportunities for training both here and abroad. Several organizations, for example the Consortium for International Crop Protection, have had marked success with training courses and workshops.

Another form of cooperation, less frequent but which needs to be encouraged, is having American scientists spend extended periods in support programs abroad. Leaving the United States and going to a developing country for an extended stay requires a major personal commitment. The most altruistic researcher needs to feel that others appreciate the contribution and effort being made. The intrinsic rewards of accomplishment for a scientist are difficult enough to come by in the well-equipped laboratories of the United States. The scientist needs a high level of tolerance for frustration in a setting where the problems are far greater, the facilities less adequate, and the results possibly longer in coming. Though universities differ in the amount of support accorded researchers who participate in international programs, each researcher risks returning to a loss of professional competence and status within his or her own discipline. Three years of not keeping up with the "right" journals and not contributing at the "edges of knowledge" may be a permanent disadvantage to professional achievement within the established system of university science. The importance of journal publications to a researcher's acceptance into an agricultural discipline is well documented (5,8). In a system in which the young scientist is in jeopardy of "perishing" if he or she does not publish, it may be only older, established scientists who can afford to participate by going abroad for long periods.

Very often the pattern has been for American scientists to go to other countries for short periods, essentially as consultants. Though this may be helpful, the cooperation is unlikely to take sufficient cognizance of the constraints on effective research. A better system seems to be a long term relationship between institutions of agricultural research in both countries,

involving occasional travel, but consistent communication. In this way, whole groups of people learn one another's problems, approaches, and idiosyncracies.

It is unfortunate that much of our society considers the practice of agriculture to be menial labor, requiring no skills beyond placing seed in the soil and harvesting the end product. In the industrial revolution, it was sophisticated to leave the farm for the city. People who remained on the farm were increasingly deemed those who could do no better. This concept of agriculture has continued, although the levels of scientific and technological expertise which underlie the practice of agriculture have increased dramatically. Unfortunately, the concept spans the agricultural community the world over. As long as agriculture, and agriculturalists, and people who deal with agriculture as their source of livelihood are looked down upon by those outside the agricultural community, we are going to have a hard time solving the problem of hunger. This is the cardinal problem of incentive. It does not matter whether we are looking down on an American Ph.D. doing basic research in a laboratory or on a Nigerian farmer with her hands in the soil. People associated with agriculture are considered DUMB.

The paradox in the United States is that much of society both looks down on agriculture as menial and romaticizes agriculture as a simpler, less frenetic way of life. Now, given the attention to environmental protection, displacement of people from farming, and the energy intensiveness of agricultural practice, agriculturalists have gained yet a second burden. Farmers and scientists are held responsible for the disadvantages of technologically intensive agriculture without being credited for the abundant food in the grocery store.

A peculiar dilemma rests with those of us who practice agricultural science. Within the community of science, the "best" science is considered to be that which is purest--knowledge sought for the sake of discovery. Most agricultural science has been pursued in the clear context of practical problems to be solved. Accordingly, most agricultural scientists receive funds only when they can demonstrate that their research is directly related to solving current problems. In effect, getting from the laboratory to the field is far easier for agriculture than for other scientific disciplines. In the meantime, because of

their practical mission, agricultural scientists often suffer as second class citizens of the scientific community (8,9).

The requirement for justifying dollars for research in terms of human benefit is compatible with the way we practice our science. The problem is that the second class image also limits the funds available for research (9). Table 1 presents U.S. government budgets for basic research and for total research and development of the major science agencies for fiscal year 1982. The allocation for food-related research suggested by the Department of Agriculture's budget for basic research ($361 million) is less than one fifth the investment in basic research in medical sciences represented by the basic research budget of the Department of Health and Human Services ($2 billion). Similarly, the total allocation for research and development in the Department of Agriculture ($859 million) is about one twenty-fifth the proposed expenditure for military research and development (approximately $22 billion).

Table 1. Budget Authority for Basic Research and for Total Research and Development, by Agency, Fiscal Year 1982*

authority	basic research	research and development
	--(millions of dollars)--	
Health and Human Services	2,003	4,155
National Science Foundation	950	1,002
Department of Energy	680	4,665
Department of Defense, Military	724	21,746
National Aeronautics and Space Administration	592	6,017
Department of Agriculture	361	859
All others	210	2,518
TOTAL	5,542	40,763

* Willis H. Shapley, A. H. Teich, G. J. Breslow. Research & Development AAAS Report VI. New Directions for R & D: Federal Budget - FY 1982. Washington, D.C.: American Association for the Advancement of Science, 1982.

The final report of the Carter Commission on World Hunger (13) argues that millions of deaths attributed to infectious and noninfectious diseases are directly attributable to malnutrition. Judged by governmental support for research, U.S. priorities have been on the secondary, rather than the primary, cause of death among the poor of the world.

Somehow society has discovered migrant workers, domestic hunger, agricultural chemicals, and food additives and has decided to change or eliminate the "agricultural establishment," as if agricultural scientists were not themselves aware of the problems and working diligently and unsung to overcome them. In a vanishing constituency, where few are paying attention to research on food production and farming systems, the scientists and colleges of agriculture are apt to respond to the political pressures they are getting: the relatively narrow (not sinister) interests of those whose economic survival depends upon agriculture.

To make food-related research more relevant to hunger problems we need a broader segment of society interested in and knowledgeable about agriculture. To do that, we need to overcome the misconceptions of agriculture and agriculturalists and to demonstrate how difficult it is to solve the problems of increasing crop productivity, improving food quality, developing inexpensive and technologically simple production practices, and all the while improving or at least maintaining environmental quality. If we really want funding for the kind of science that tackles fundamental research to solve these problems, then there must also be support from the larger academic community for agricultural research. In short, we have to convince our colleagues that the science we practice is not second class!

BIOTECHNOLOGY: THE TOOLS OF THE TRADE

In order to put biotechnology into meaningful perspective, we need to consider some recent developments in agriculture. Agriculture is very much in the public eye and has recently come under considerably criticism. In 1981 a report of the Office of Technology Assessment pointed to a lack of appreciation for basic agricultural research by the USDA (11). It also questioned the value

of ongoing traditional programs of research in agriculture in the face of new problems, increasing costs, and a diminishing research budget. In 1982 a conference jointly sponsored by the White House Office of Science and Technology Policy and the Rockefeller Foundation examined, and was highly critical of, the agricultural research system (17). Importantly, the participants in the conference included leading spokespersons for agriculture. Among other things, the report states that agricultural scientists lack the respect of the scientific community, that basic research is often not quality research, and that there are no consistent plans for national or international agricultural policies. The weekly journal Science brought the report to the attention of the scientific community as a whole (10) and this was followed by an eye opening evaluation of the agricultural network by Chemical and Engineering News (6).

Concurrently with these reports of inadequacies in agricultural research have come a host of articles citing new approaches to the problems of agricultural productivity both at home and abroad--and the message is that new biotechnologies will be a major factor in the increasing productivity (1,4,16). The National Academy of Sciences justifiably has recommended the development and implementation of new techniques for improving plant characteristics (7).

When confronted with the term "new biotechnology," most of us immediately perceive genetic engineering, tissue culture, protoplast fusion, and other techniques of modern laboratory biology. It may come as a surprise, but some of us in agriculture use those tools. However, some of us question their validity because we don't understand them. We are all faced with the reality that they are being hailed in several sectors as the solution to the problem of productivity both at home and in the developing nations. There is no question that these technologies will eventually have a positive impact on agriculture throughout the world. But, I question whether the present image of agriculture has placed us in danger of relinquishing research funds sorely needed for developing new tillage and cropping practices, coping with the environment, understanding stress physiology, and the myriad of other fundamental questions pertinent to agriculture (2,12,15).

Nyle Brady, Senior Assistant Administrator for Science and Technology for USAID, recently pointed out that "one of the most serious scientific challenges

of the next two decades is to develop farming systems to replace or improve shifting cultivation systems" (3). He further emphasized the magnitude of the problem with the statistic that some 240 million people in the developing nations live by shifting cultivation. And, as populations increase, pressures on the fragile land become greater. In his article on third world agriculture and biotechnology research, M.S. Swaminathan (16) suggested a number of ways that the tools of modern biotechnology are important if increased production is to be realized. Among them were genetic engineering, tissue culture, and protoplast fusion. He also discussed the use of blue-green algae as nitrogen fixing agents for wetland rice production and the development of "small scale village biotechnology" for preparation of algae inoculum.

In seems to me that if we are to seriously enter into the effort of agricultural development, we need to follow some rules: make the commitment to understand what the problems are; convince our colleagues that the tools we have to offer and our understanding of field problems are invaluable; treat the technologies we employ as tools of our trade and demonstrate that it is the fundamental research that we are capable of that is important.

M.M. Schreiber has clearly stated a case for the concept of the modernization of weed science and research in weed biology (14). It applies equally to all disciplines of crop protection. Weed science, entomology, and plant pathology are no longer emerging sciences with the need for descriptive research. Only the difficult problems remain and their solutions lie in the cooperation of fundamental researchers regardless of the tools they use. As M.S. Swaminathan so correctly pointed out, "solving a problem rather than worshipping a tool should be the goal" (16).

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OVERVIEW OF REGIONAL WEED CONTROL REQUIREMENTS WITHIN CERTAIN DEVELOPING COUNTRIES[1/]

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INTRODUCTION

The objective of the weed scientists is not just to control weeds *per se* but to grow more crops from available land not only in the short-, but also in the long-term. As the agro-ecosystems become more precarious, he must be ever conscious of this statement. A major geographical zone where this statement applies is Central/North Africa where there are broadly three ecological zones largely defined by rainfall; the dry unimodal rainfall area, and the biomodal rainfall area, which merges into the semi-humid tropics. The scope of this paper is confined to the problems of the small farmers in arable land in these zones.

Here, the basic weed problems are very broadly defined as parasitic weeds, perennial weeds, and annual weed species. If inputs of water and nutrients are added to the first two zones, C4 species tend to increase or dominate. Sorghum (*Sorghum sp* Moench.) and cassava (*Manihot sp* Adans.) are survival crops here, while maize (*Zea sp* L.) is showing relative preference in many areas.

1/ The views and interpretations in this publication are those of the author and should not be attributed to FAO or any other Organization.

In general, herbicides are not employed by the small farmer and weeding time may vary widely from 20% to 60% of his total effort in crop production. Shifting cultivation is more common in the bimodal and semi-humid areas than in the dry unimodal area. Land clearing, a more common requirement in the higher rainfall zones, is usually carried out during the dry season and burning is an integral part of the operation. The level of good weed management is low and there is a direct correlation between the status of weed control technology and food deficits, though this correlation may mean very little in absolute terms. Moisture (deficits) plus unpredictable rain distribution have the greatest influence on the growth of any particular crop.

AGRONOMIC PROBLEMS OF THE SMALL FARMER

Land clearing. Many of the survival weed species reproduce vegetatively. Burning and shallow cultivation tend to activate recovery growth. In the past, when more land was available, the small farmer avoided the areas supporting the most difficult-to-control weeds. This often meant moving further away from the village and this increased transport difficulties and protection of the crop from grazing animals. Normally, initial clearing and land preparation took about 20% of the farmer's total time. The first cultivation was usually the deepest in order to remove as many rhizomes as possible.

Fertility. The most fertile zones are normally in the environs of the village. In the past, bush fallowing was instituted to improve soil fertility. However, burning oxidizes nitrogen and, with shorter bush fallow rotations, the land after several seasons was abandoned due to weeds rather than to low soil fertility levels (1).

Moisture. Often moisture dictates the type of cropping. In some areas, maize is showing preference over more traditional crops as it requires less protection against avian predators. In bimodal rainfall areas where the first season is short, planting of maize at the onset of the rains may reduce the risk of moisture deficits at later critical growth stages of the crop. However, land preparation is not commenced until after the onset of rains because the soils are hard and the animals used for tillage are weak after a prolonged dry period.

Planting and weeding. Land preparation and planting, which may be done sequentially, take precedence over weeding. Even where labor is divided among family members--where the man does the land clearing, the wife or wives do the land preparation and planting, and the children do the weeding--bottlenecks occur, particularly with improved varieties that require early weeding. In addition, while animals may be trained to plough in a regular fashion, few animals are trained to the degree of precision required to inter-row weed, and their use may result in excessive crop damage.

CONSTRAINTS IN WEED CONTROL

The possible reasons why improved weed management is not utilized more widely are summarized as follows:

Lack of awareness. Much of the sophistication in weed management has only been developed in the last two decades. However, there is inadequate flow of information on what can be achieved at the farm level in most developing countries. The overplay of possible environmental contamination by plant protection chemicals, including herbicides, has, instead, reached many more ears than good weeding management. This lack of information probably represents the greatest constraint to improved crop production. Further, the effectiveness of biological control techniques and the rapid advances made in the selection and propagation of semi-resistant and resistant varieties for insect and plant pathogen control has tended to ease the requirement for plant protection at the administrative level. The awareness that these technologies have distinctly less applicability at present for control of weeds has not been clearly differentiated at the same level of administration.

Capital inputs. Often the lack of capital is given as the reason for the nonuse of herbicides. However, even in countries of the developing world, rich in certain resources and capital, little or no improved weed management is conducted at the small farmer level, while even relatively poor countries rate their own progress in terms of mechanization in agriculture, i.e., the amount of sequestered energy per head of agricultural population.

THE ROLE OF IMPROVED WEED MANAGEMENT

Improved weed management at the small farmer level needs to be better defined. In land clearing and preparation, useful vegetation (by planting a vigorous legume) may be more appropriate than the conventional use of herbicides or mechanical equipment. In the semi-humid areas particularly, research data show that crop establishment is hazardous where crops are established without a protective microclimate (permanent ground cover) (2). If useful vegetation, such as legumes, is employed as the main weed control tool, less herbicides are required. Within a fragile or precarious agro-ecosystem, intra-row weeding should receive priority and the inter-row weeds should be left as long as possible. At most, herbicides should be employed to assist the farmer to better schedule his weeding operations by controlling the first flushes of susceptible weeds rather than for the control of all weed species present.

Further, the inter-relationship of increased mechanization and improved weed management requires closer evaluation at the small farmer level. Where comparisons have been made, weeding at the small farmer level is more efficient than that of co-operatives and co-operatives, in turn, are more efficiently weeded than most larger scale state farms or support programs, i.e., the efficiency of weeding appears directly related to the size of the holdings and the degree of mechanization. From this generalization, improved weed management must become an integral part of larger scale enterprises if improvements in production and methodologies are to be attained.

The problem of partial rather than complete mechanization has to be considered also for the small farmer. This is instanced where a farmer has animal power, but his resources limit his agronomic practices to a single implement which is usually a mould-board plough. He may attempt to even be encouraged to employ this equipment as a weeding tool. In precarious or fragile agroecosystems, ploughing and seeding a single furrow rather than tilling the whole of the inter-row area had distinct advantages, but again this practice depends on herbicides for full efficiency, particularly if the chemical fallowing technique is to be employed as a method of lowering the carbon-nitrogen ratio and to provide improved control of rhizomatous species.

AN ACTION PROGRAM

Clearly, any action program to promote improved weed management must have roots at all levels from the small farmer to the administrator. Priority must be given to creating awareness of the importance of improved weed management and this may depend on opening the necessary lines of communication. In many cases, the lines of communication are fully loaded, and the small weed control package may have to compete with multi-million dollar grants or inducements for other programs in a country where human resources are not limiting. An improved action program may necessarily have humble beginnings, but could include the following:

Pooling of resources. The Weed Science Society of America (WSSA) is a glowing example of pooling national resources at many levels. The staging of the Food and Agricultural Organization (FAO)/International Weed Science Society (IWSS) Expert Consultation on Improving Weed Management that was supported by all the regional weed science societies, some national and international agricultural research centers, and industry, is another example. The impact of the Expert Consultation is likely to be much greater as a result of such wide support. However, there is not machinery established at the regional and international level to improve the increasing necessity to pool resources in weed management. The establishment of an international panel would focus attention on this important aspect of improving weed management, but the desire and initiative to pool resources must come from all levels.

Talking to others. WSSA has undertaken a deliberate policy of focusing attention on the role of improved weed management at all levels within North America. The role WSSA has played has no parallel. The thrust of the recent FAO/IWSS Expert Panel had the same objective and developed approximately 100 recommendations for the improvement of weed management at country level and defined to whom the recommendations should be sent. If each recommendation(s) could be drawn to the personal attention of the person(s) it concerns most directly, then the impact is likely to be greater. A simple colored brochure, graphically showing comparisons in methodologies and likely benefits to accom-

pany each recommendation, is likely to impact further. The preparation and publication of such a brochure is within the resources of a combined effort, i.e., pooling of resources.

Training of expatriate students in the problems of the small scale farmer. In one overseas development program, a notable weed scientist has taken his sabbatical leave in a developing country. Two of his students are assisting by doing their thesis work on local problems. This type of program should receive the highest attention. Also, universities in the developing countries would benefit from more people taking their sabbaticals at those universities.

Training the trainer. As part of the FAO Action Program on improving plant protection, two training programs are being staged in West Africa utilizing the expertise of the International Plant Protection Center (IPPC). Considerable effort by the IPPC and others is being expended to ensure the training programs receive the widest publicity and support so that future demands may come from country level. All weed scientists and weed science societies could assist with creating the demand for training.

Fostering a weed scientist. Not all weed scientists, on returning after overseas training, are able to carve a niche and break out of the fetters of few facilities, no publications, and no one to turn to for advice and/or assistance in formulating a program, friendly advice on publications, etc. They remain nonentities and overall their productivity may be low. Their whereabouts or existence may remain obscure. A society such as WSSA, or even individual members, could locate said weed scientists and offer assistance, even membership in WSSA, so that the person concerned has some support, and someone to turn to.

Annual review of weed science. Small working groups within WSSA could compile biennially the literature on specific crop(s) of importance in the advancing countries and process the information as a reference source. If the foundation work was undertaken, by pooling resources, publication and distribution should be possible.

FAO Plant Protection Bulletin. Strictly this is the mouthpiece of the Plant Protection Service of which weed management should be a vital element. The Bulletin is published quarterly and is distributed to all (152) member countries of FAO with summaries in three languages. In the past, the Bulletin contained few articles on technology transfer. New proposals call for a supplement on technology transfer. Weed scientists have an open opportunity to publish impact information. A limited number of author's contracts are available to promote the preparation of suitable data.

Accepting the challenge. The challenge to up-grade weed management is open and the impact at country level is likely to be considerable. WSSA, in staging a symposium of Technology Transfer, has taken one step forward.

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THE STATUS OF WEED SCIENCE IN ZAMBIA AND THE NEED FOR INCREASED TRANSFER OF WEED CONTROL TECHNOLOGY

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INTRODUCTION

Zambia. Zambia is a land-locked central African country of some 290,000 square miles with 20 people per square mile. We have a wet summer with around 1,000 mm of rain falling in 5 months, and a dry cool season with occasional frost.

Table 1. Categories of Farmers in Zambia

farmer category	number	description
1. Traditional	500,000	Hand cultivation; little or no purchased inputs; farms less than 5 hectares.
2. Emergent	5,000	Hand, ox or tractor cultivation; range of purchased inputs but at sub-optimal levels.
3. Large scale commercial	1,000	Highly mechanized; intensive use of fertilizers, pesticides, herbicides, purchased seeds, credit. Cover perhaps 100,000 ha of cultivation.

These categories are necessarily arbitrary and the farmer numbers very approximate.

Source: Vernon: personal communications with Zambia Department of Agriculture staff.

Table 2. The Main Cash Crops of Zambia

crop	approximate marketed area (ha)
1. Corn	300,000
2. Sunflower	50,000
3. Peanut	40,000
4. Cotton	25,000
5. Sugar Cane	11,000
6. Soybean	10,000
7. Wheat	4,000
8. Tobacco	3,000
9. Rice	3,000

These figures exclude the often substantial areas grown by small holders for local consumption, including finger and bulrush millets, sorghum, and cassava.

Source: Vernon personal communications with Zambia Department of Agriculture staff.

Zambian agriculture. Farming in Zambia is diverse ranging from villagers who aim to grow little more than they need to eat, to large, highly-mechanized estates with intensive use of agro-chemicals. A crude breakdown of farmer categories is given in Table 1. Zambia's major cash crops are listed in Table 2.

Weed control research. The agricultural research branch has about 90 professional staff which includes a single weed scientist. The main thrust of the weed research programme over the last 9 years has been a screening of herbicides suitable for our main cash crops under local conditions. More than 50 herbicides have been tested in this programme, which has resulted in several new products being made available on the local market. Products currently on sale in Zambia are listed in Table 3.

There have been smaller programmes on the problems faced by the ox cultivator which are described later, on herbicide application equipment, and on a survey of the country's arable weeds.

Table 3. Herbicides Sold in Zambia and Estimated 1981 Use.

		(1000kg of % concentration shown)			
Alachlor	48%	17	Linuron		?
Atrazine	50%	131	MCPA		?
Bentazon	48%	0.8	Metolachlor	72%	66
Bifenox	80%	?	Metribuzin	70%	1.4
Bromacil	80%	0.3	MSMA		?
Cyanazine	56%	?	Paraquat	20%	14
2,4-D 48 &	72%	15	Pebulate		12
Dalapon	85%	?	Picloram		?
Diclofop	36%	?	Pendimethalin		?
Difenoxuron	50%	?	Prometryne	50%	3.6
Diquat	20%	?	Propachlor	65%	?
Diuron	80%	?	Simazine		?
EPTC	72%	9	2,4,5-T		?
Fluometuron	50%	?	TCA		?
Glyphosate	36%	3.5	Terbutryne		?
Ioxynil		?	Trifluralin	48%	4.3

?= amount unknown, but probably less than 1.0 tonne.

Source: Vernon personal communications with manufacturers and distributors.

THE NEEDS OF A WEED RESEARCH PROGRAMME

Staff. Experienced weed scientists are rare in developing countries and skilled technicians even more so. It is possible to operate without the latter, but no programme is likely to commence without the former.

Government awareness and funds. A weed researcher was appointed in Zambia in 1973, but there were no funds set aside for his programme. Any expenditure had to be met out of general station funds, which were generally inadequate.

By 1977, some good research had been done and some new herbicides had appeared on the local market, but funding was a major limiting factor. A one-page article was then put in the local farming magazine, entitled "The Expensive Weed," in which it was pointed out that a conservative estimate of 15% loss due to weeds in the country's corn crop means a national loss of $10 million in lost crop. This was picked up by the main daily newspaper which gave

it further coverage. The following year the weed research budget for $27,000 was granted in full. Since that time, an active programme has been pursued and comprehensive reports issued annually--and funds have been adequate.

Knowledge of local farming practices. The practices followed on hand and ox cultivated farms are very different from those of the large tractor-based farms in Zambia. Equally important, the methods used on small farms differ widely from one region to another. Their problems, labour bottlenecks, and opportunities for change vary similarly and need to be understood by the weed agronomist before there is much chance of him bringing about any improvement at their level. This matter is taken up again later.

Knowledge of local weeds. Current knowledge of weeds amongst Zambian extension agents is low: the ability to name 10 common weeds is exceptional. Zambian farmers can often do better, but the position is made difficult by the large number (around 76) of local languages. Vernacular names are often less precise than botanical names: similar species and even genera are sometimes given the same name. But then, the botanist's level of precision is not always needed on the farm. Vernacular names are often more interesting: mtandaimbu, the cinyanja name of hoary basil (*Ocimum canum* Sims), comes from mtanda, to chase, and imbu, mosquito. The smell produced when this weed is beaten against the walls of a house repels mosquitoes.

There is amongst villagers a large, though rather dispersed, pool of knowledge of the ecology of many plants, including weeds, which could usefully be tapped.

There is little taxonomic expertise available in the country and plant specimens have to be sent abroad for internationally acceptable determinations.

Floras and weed guides. There are some 'second bests' available. The Flora Zambesiaca, which aims to cover the Zambezi River catchment area of Botswana, Mozambique, Zambia, and Zimbabwe, will eventually be the definitive answer for the specialist, but is still far from complete, covering at present only six

of the 23 families containing common Zambian weeds. The Flora of Tropical East Africa is much further advanced, but there are differences between the vegetation of that area and ours.

Floras are of use to weed specialists, but not in general to farmers. There exists a mimeographed booklet on Zambian weeds, but it is limited to black and white line drawings of variable quality and brief descriptions using technical terms understood by very few people. We are in the final stages of preparing a new colour-illustrated Field Guide to Important Arable Weeds of Zambia which includes, besides colour photographs, notes on recognition, similar weeds, distribution, etc. Production of this guide has only been made possible through the coincidence of a weed scientist interested, and present long enough, to produce it, and a donor, in this case Sweden, willing to pay for it.

Technical information. The critical dependence of the weed scientist in a developing country on a reliable flow of information from the mainstream of weed research elsewhere in the world, is described in a later paper by Fischer and Vernon. In this paper I would like to concentrate on technology transfer within a developing country. Before I do so, it is necessary to consider some special characteristics of the small-scale farm, at least as it is found in one such country.

COMPLICATIONS OF THE SMALL FARM

Contrast with large farms. Weed control research in Zambia has had a much greater impact on large farms than on small farms. Large farms, which readily take up new products and concepts in chemical weed control, actually have a multi-million dollar industry working for them. The local researcher has the fairly straightforward task of selecting out those that are locally appropriate.

Small farms usually lack the technical skills, financial resources, and marketing services to make use of chemical weed control and are therefore cut

off from this huge research and development effort. This will remain so until all three of these factors are brought to the small farm by extension services, lending agencies, and suppliers respectively. This is unlikely to happen in the near future.

The only way for a small- scale farmer to plug in to the chemical weed control industry is for him to pull himself up the farming ladder to within the range of these three factors. The only short cut that can presently be envisaged is the reduction in the requirement of technical skills through the invention and distribution of simpler methods of herbicide application. The early hopes we had that battery-driven spinning disc applicators would do this, proved premature (3): they are still too complicated to spread spontaneously without intensive extension support, and they are too dependent on the timely supply of herbicides, batteries, and farm loans.

Largely precluded from chemical control methods, the small farm has to rely on mechanical control. The implications of this differ with farming system, and table 4 shows how for five systems described by Bessel (1). These data indicate that weeding absorbs more labour than any other operation. But it also shows wide variation in the labour requirements of weeding: some farmers are deriving seven times the yield per hour of labour than others. This should offer scope to the agronomist for identifying improvements.

This leads us to another complicating factor of small farms: it is not enought to show, as with a herbicide, that a particular method controls certain weeds. If we are to discover methods with a good chance of proving useful, we have to involve such factors as the labour requirement per hectare, the yield increase per unit of labour, the variation of labour demand through the season, the availability of labour in a family and its variation (for example, during school holidays), and finally, its opportunity cost. The last is the cash value of labour if deployed in alternative ways.

Table 4. Labour Use for the Main Operations in Maize Cultivation on Small Farms in Zambia.

farming system	operation: plant	weed	harvest	yield
	--(man-hours/ha)--			(kg/labour hr)
1. Plant by hand, broadcast, local variety	112	452	66	0.68
2. Plant by hand in rows, local variety	95	351	178	1.1
3. Plant behind plough, local variety	32	166	74	1.6
4. Plant behind plough, improved variety	18	80	84	3.8
5. Plant with planter, improved variety	15	44	63	5.0
Mean of five systems	54	219	93	2.4

Source: Bessel, 1973.

Thus, weed control studies on small farms in the developing world need to include social and economic factors as much as, and perhaps before, technical ones. A precursor of the latter may have to be a fairly detailed description of local farming systems. This is a formidable task, but a start has been made in Zambia by a CIMMYT-sponsored programme (2).

TECHNOLOGY TRANSFER WITHIN ZAMBIA

The agricultural extension service. Zambia employs some 1,400 extension staff including approximately 80 university graduates, though none have specialist weed control training.

Big farms. The large scale farmer who uses herbicides can be reached by articles in the Commercial Farmers Bureau's own monthly, 'Productive Farming.' This works fairly well and I put an updating article in every year or two. These farmers are able to come by car to the Central Research Station and seek advice directly from specialist researchers, and they frequently do so.

Small farms. The researcher often has much less contact with either extension staff or with small-scale farmers. This is partly due to less research having been applied to this sector, in which herbicides are not generally used. But it is also due to the difficulty of communicating with 1,400 extension workers and half a million farmers scattered in many remote areas. The Department of Agriculture publishes a periodical, 'Farming in Zambia' with usually three to four issues a year. Although 300 copies are said to be printed, distribution is poor: several extension workers have told me they rarely see a copy.

Information storage and dissemination. A large amount of agricultural research has been done in Zambia over the past half century. Much of it is now available only with difficulty, in reports that have often become rare with time. We hear a great deal these days of the importance of preserving genetic resources of plants and animals in gene banks for future breeders to draw from. I would submit there is a similar need for information banks to be established in developing countries. This need has two parts: information must be stored so that it is never lost, and a system must be established that allows a very scattered population of extension and research staff to have access to it. The former should not wait for the latter as the need to preserve existing material is urgent. As senior staff retire and expatriates return home, even the knowledge of the existence of many publications is being lost.

It is tempting to think of a central storage facility linked to terminals in each of the country's nine provinces and other key points such as institutes of higher learning. The prospect of having distant extension staff able to tap the large body of existing information is exciting.

And yet we do not know if such a system can be made to work in the developing world, where it is a struggle to maintain even a telephone system at a reasonably operational level. What we do know is that there is a serious loss of knowledge between the researcher and the farm gate. To allow this dissipation to persist at its present level makes something of a mockery of funding further research. In Zambia the Research Branch produces an annual report of about 300 pages per year, an average of some 3 pages per professional staff member. Yet those of the last 6 years have not been issued as they are still waiting to be printed.

Prior to the evaluation and possible implementation of sophisticated computer-based information storage and distribution systems, the establishment of research-extension liaison staff and publication and copying facilities offer great scope for enhancing the short and long term productivity of research.

Training. Mention was made earlier of the absence of extension staff trained in weed control. The need for such training for both extension and trainee research staff is great, but its implementation difficult. Numerous scholarships are available in the developed countries, but the relevance of such training, often in a temperate climate and under high capital, low labour conditions, is questionable. It is possible a student could return home after completing a weed science course overseas and be familiar with a logarithmic sprayer (though there is none available in his country) and yet be unable to identify a single local weed.

It seems preferable to run a weed science course in or near the country of the trainee: such a course could usefully serve half a dozen adjacent countries with similar climates, crops, weeds, and economic and technical backgrounds. It would then be important to ensure that the trainers were well versed in local conditions. If expatriates are needed, which is likely initally, 5-year contracts are much to be preferred over 1-year terms, and conditions need to be set to render such a period acceptable to the person concerned. One of these conditions would surely have to be greatly improved weed science communications, both inside the country and with the outside world. The setting up of such a training course would provide an admirable opportunity to establish these communications.

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ECOLOGICAL FUNCTIONS AND INTEGRATED CONTROL OF FARM AND GARDEN WEEDS IN MAINLAND CHINA

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CONCEPT OF WEEDS AND NOXIOUS WEEDS

Farm and garden weeds are neither wild nor cultivated plants. However, they still retain some characteristics of wild plants by producing a large number of seeds and shedding them as soon as they become mature (Table 1). On the other hand, they have characteristics of cultivated plants. For instance, due to the influence of farm practices which have long been adopted in China, both rice and its "companion weed," barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.], have early, median, and late maturing varieties (or ecotypes), though they belong to the same species with the same morphological aspects. If the late variety of barnyardgrass happens to grow with an early or median maturing rice ecotype, it can only cause damage during the growing season, but cannot complete its life cycle and produce seeds.

Table 1. Number of Seeds Produced from a Single Weed Plant

weed	seeds produced
Amaranthus retroflexus L.	500,000 - 1,000,000
Chenopodium album L.	50,000 - 70,000
Sonchus arvensis L.	15,000 - 20,000
Cephalanoplos setosum (Bunge.) Kitan.	30,000 - 40,000
Cuscuta chinensis Lam.	800,000 - 1,000,000
Orobanche cumana Walli.	60,000 - 100,000

The so-called noxious weeds require three qualifications: first, they occur abundantly in the field; second, they are difficult to eradicate; and third, they cause major reductions in the yield of crops. Fortunately, the number of species of noxious weeds is quite small. A comprehensive classification of noxious weeds is made according to their ecological and biological characteristics (Figure 1). Most common weeds occur in rice (Oryza sativa L.), wheat (Triticum aestivum L.), cotton (Gossypium hirsutum L.), and soybean (Glycine max (L.) Merr.) fields, and farm weeds of different seasons year round are grouped and subdivided into several categories. As shown in Figure 1, some weeds are parasitic and some are nonparasitic. Some weeds are annual, biennial or perennial. Some weeds are produced mainly by seeds and some by vegetative organs.

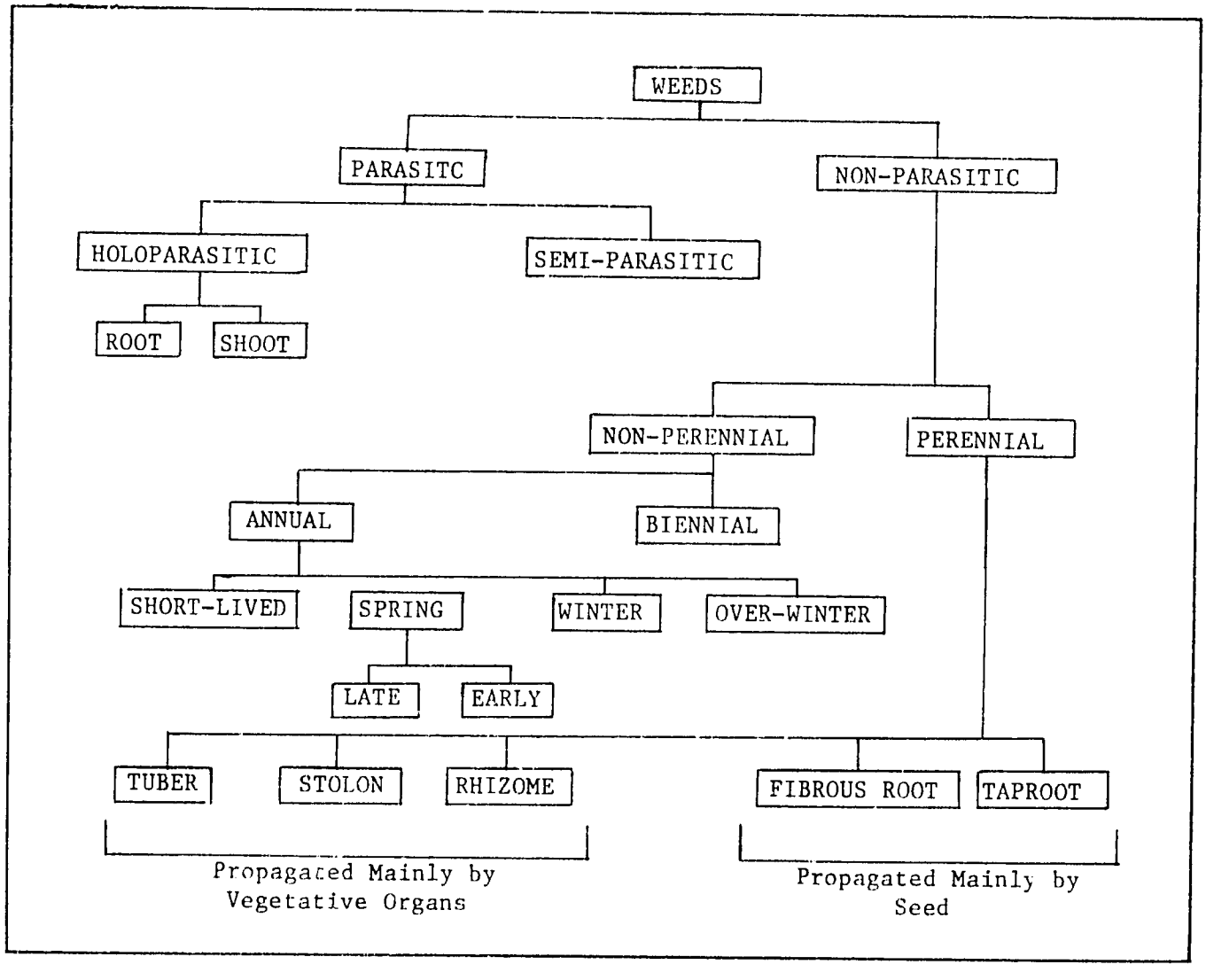

Figure 1. Classification of noxious weeds.

Natural environment and cultural practices have important effects on farm and garden weeds. The interaction between weeds and the environment and the response of weeds to environmental effects are both very prominent. The morpho-ecological and structural characteristics of weeds are obvious expressions. Among the environmental factors, the influence of non-living factors, such as light, is very conspicuous. Competition for light in plants may operate throughout the life cycle. For instance, in some fruit growing gardens in Xinjiang Autonomus Region, barnyardgrass and common lambsquarter (Chenopodium album L.) scattered here and there in the interspaces in the gardens may reach a height exceeding that of an average man.

Table 2. The Relation of Water Depth to Different Weed Ecotypes

weed ecotype	biological type and example	water affect
Xerophytic (in dry fields)	Annual, as green bristlegrass, and perennial, as thistle, weeds.	Weeds die at a water depth of 5-10 cm.
Mesophytic (average or optimum water supply)	Annual weeds, as barnyardgrass.	Growth of dry and water field barnyardgrass is suppressed at the depth of 15 cm and 23-35 cm, respectively.
Hydrophytic (Roots underwater; part of the shoot is above the water surface)	Annual, as monochoria, and perennial, as water plantain, weeds.	Weeds die when water is insufficient.

Weeds are also very sensitive to water supply. In Table 2, some examples are given to show the effects of water on weeds. We may take knotgrass (Paspalum distichum L.) as another example. This grass, thriving on water-soaked land, does not grow well when the water is too deep. Knotgrass grows along the margins of rice fields and will encroach upon the fields when there

is optimum or average water supply. Because of the presence of water, the number of species of weeds in rice fields is limited, and they all have the same characteristics--tender in texture, without cuticle layer, and with thin epidermis poorly developed vascular bundles, and large air spaces. The entire weed plant is suitable for the absorption and translocation of herbicides. This is the reason why herbicides are used successfully in rice fields to combat weeds.

Soil constituents, especially salt in saline soil, bear a close relation to the kinds, distribution, and growth of crops and weeds. For instance, the principal weeds in newly cultivated regions near the sea are grouped in accordance with the salt content in the soil.

A soil with high salt content and with no plants growing on it is called "bare plate." Salt-adaptable weeds, such as Suaeda glauca Forsk., have xerophytic and succulent structures of the stems and leaves and elaborate structural modifications, which are much like those found in plants of the desert flora. Salt-tolerant weeds, such as Aeluropus littoralis, are not typically xerophytic in structure. The water, though present, is of such high osmotic concentration that it cannot be readily absorbed by the plants. Soluble salt is accumulated within the cells. Salt-secreting weeds, such as Statice bicolor, have secreting cells in the stem and leaves. Salt is secreted continuously to the surface and is washed away by rain. After the improvement of the soil conditions, the importation and the growth of weeds and the wide dissemination of noxious weeds make the weed control problem in these regions more complicated.

In addition to nonliving factors of the environment, the interrelationship between weeds and living factors is also very complicated. Some weeds, such as common vetch (Vicia sativa L.), field bindweed (Convolvulus arvensis L.), Japanese hop (Humulus scandens Merr.), and catch weed bedstraw (Galium aparine L.), climb on the crops, thereby interfering with the harvest procedure. Some weeds are semi-parasitic, such as European mistletoe (Viscum album) and Cassytha filiformis L., which live on fruit and timber trees. Some are obligate holoparasitic weeds, such as dodders (Cuscuta sp.) and broom-rapes (Orobanche

sp.) living on crop plants. Some weeds may be invaded by insect and fungi pests, and as a result their growth is inhibited. This can serve as a means of biological control of weeds. In China, the influence of the environment on both weeds and crops is very complicated.

THE RESPONSE OF WEEDS TO THE INTEGRATED INFLUENCE OF ENVIRONMENTS

In case of Jiangsu Province is taken as an example to show the response of weeds to the integrated influence of ecological environments. Jiangsu Providence is situated as a transition region from the warm temperate zone to the subtropical zone. The temperature and precipitation increase gradually from the north to the south. Therefore, the response of crops and weeds, in their kinds and distribution, to the environmental effects is in definite regularity. The kinds and distribution of weeds correlates with the change of latitude. There are about 392 species belonging to 72 families. The difference in the number of families and species of weeds in the various agricultural sections of this province is very evident. In each region, the number of families with four species is different from each other. Changes in vegetation also occur in different topographic regions. Because of the complicated topography, the mountainous region has more families and species. The region along the sea shore with saline soil has fewer families and species (Table 3).

Table 3. Number and Distribution of Families and Species of Weeds in Six Agricultural Sections of Jiangsu Province

section	families	species	families with more than four species
Northern	29	134	12
Central	39	39	6
Sea shore	24	82	5
River shore	63	270	22
Mountainous	71	314	17
Taihu Lake	47	193	13

There are 25 species of common weeds in rice fields and among them seven are most noxious (Table 4). Weeds in dry land (wheat, cotton, corn, soybean, and peanut fields) are comparatively complicated. There are 47 species, and eight of them are noxious ones (Table 5).

Farm weeds are in their most vigorous growth in May, June, and July. Summer crops are damaged seriously, and manpower for hand weeding is in great demand. In the Central section with a central basin low land, there are quite a number of aquatic weeds. In the sea shore section, the soil contains a high percentage of salt, and only salt tolerant weeds are found. All this definitely indicates that natural or ecological factors have their integrated influence on the kinds and distributions of weeds.

Table 4. Noxious Weeds in Rice Fields

botanical name	common name
Echinochloa crus-galli (L.) Beauv.	barnyardgrass
Paspalum distichum L.	knotgrass
Cyperus difformis L.	small flower umbrellaplant
Scirpus planiculmis (Fr.) Schmidt	bulrush
Eleocharis yokoscensis Franch & Savat.	spikerush
Fimbristylis miliacea (L.) C.B. Clarko	fimbristylis
Potamogeton distinctus A. Benn	pondweed

Table 5. Noxious Weeds in Dry Fields

botanical name	common name
Setaris viridis (L.) Beauv.	green foxtail
Alopecurus aequalis Sobol.	foxtail
Galium aparine var. *tenerum* Gron. & Godis. Robb.	catchweed bedstraw
Cyperus rotundus L.	purple nutsedge
Vicia sativa L.	common vetch
Stellaria media (L.) Cyr.	chickweed
Avena fatua L.	wild oat
Eleusine indica (L.) Gaertn.	goosegrass

INTEGRATED CONTROL OF WEEDS

Practice has proved that each control method has its own limitations. There are disadvantages as well as advantages. Single application of herbicides cannot satisfactorily control weeds. The desirable process is to apply ecological principles such as biological suppression of weeds together with the application of herbicide treatment during the early stage of weed growth. In order to accomplish this, we must initially survey the weeds and the damage caused by them, and then select the most noxious weeds and study their biological characteristics. Herbicides should be applied to control the weed in the early stages, so that the number of weeds can be suppressed to the minimum and the crop can grow in a favorable condition. In this way an integrated controlling system is established.

Yield has been the most sensitive indicator of weed competition. For instance, we plant soybean or sesame in rows in the interspaces between fruit trees to inhibit the growth of many weeds. As a consequence, the fertility of the soil is increased, which enhances yield. We plant sweet potato (*Ipomea batatas* L.) or mimosa (*Mimosa* sp. L.) plants in the rubber tree garden to reduce

the damage caused by a most noxious weed, cogongrass [Imperata cylindrica var. major (Nees) Hubb.]. These intercropping systems have proved very beneficial.

Another example is the weed control system in cotton fields in the southern part of China. Formerly, in order to suit the long growing season of the cotton plant and to get more yield, growers planted cotton early in the season when the temperatures were still low. Early seedings (April 20) and low plant populations (4-5 thousand plants per mu[1/]) were utilized. The crop's slow early growth permitted early vigorous weed competition. Extensive soil tillage (5-6 times) was the primary method of controlling weeds. Repeated fertilizer applications were made in order to increase the boll number per plant. The cropping and weed control system has been altered by seeding after spring harvest (in May), thus avoiding the attack of cutworms and increasing the plant population (15 thousand plants per mu, row space 20 cm). Under this system, no tillage is needed. Early weed control is achieved with a herbicide (5% fluometuron, 1-1.2 catties[2/] per mu) for 22-27 days. [illegible]eturon reduces the damage caused by barnyardgrass, fingergrass (Chloris sp), green bristle-grass, shepherdpurse [Capella bursa-pastoris (L.) Medic.], bermudagrass [Cynodon dactylon (L.) Pers.], nutsedge (Cyperus sp) and field bindweed by 90%. Fluometuron is used to eradicate most of the weeds in the early stage and the density of the crop inhibits the growth of weeds during the whole growing season.

Now the length of the growing period of cotton is shortened by 50 days, the labor required is reduced by 50%, the production cost reduced by 30-40%, and the yield of cotton is 50-200 catties per mu. Weeds grow less vigorously among cotton plants planted in narrow rows and yield is increased by condensed spacing. This provides a sound basis for the combination of ecological function with chemical control. This integrated controlling method for weed control in cotton fields is now applied in many provinces. In China, a practical integrated weed control system should be the most economical combination of individual measures

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1/ mu (a unit of area) = 0.0667 hectares.

2/ catties = 0.5 kilogram.

to produce optimum weed control with minimum environmental and health hazards. This might be the future trend of weed control in mainland China.

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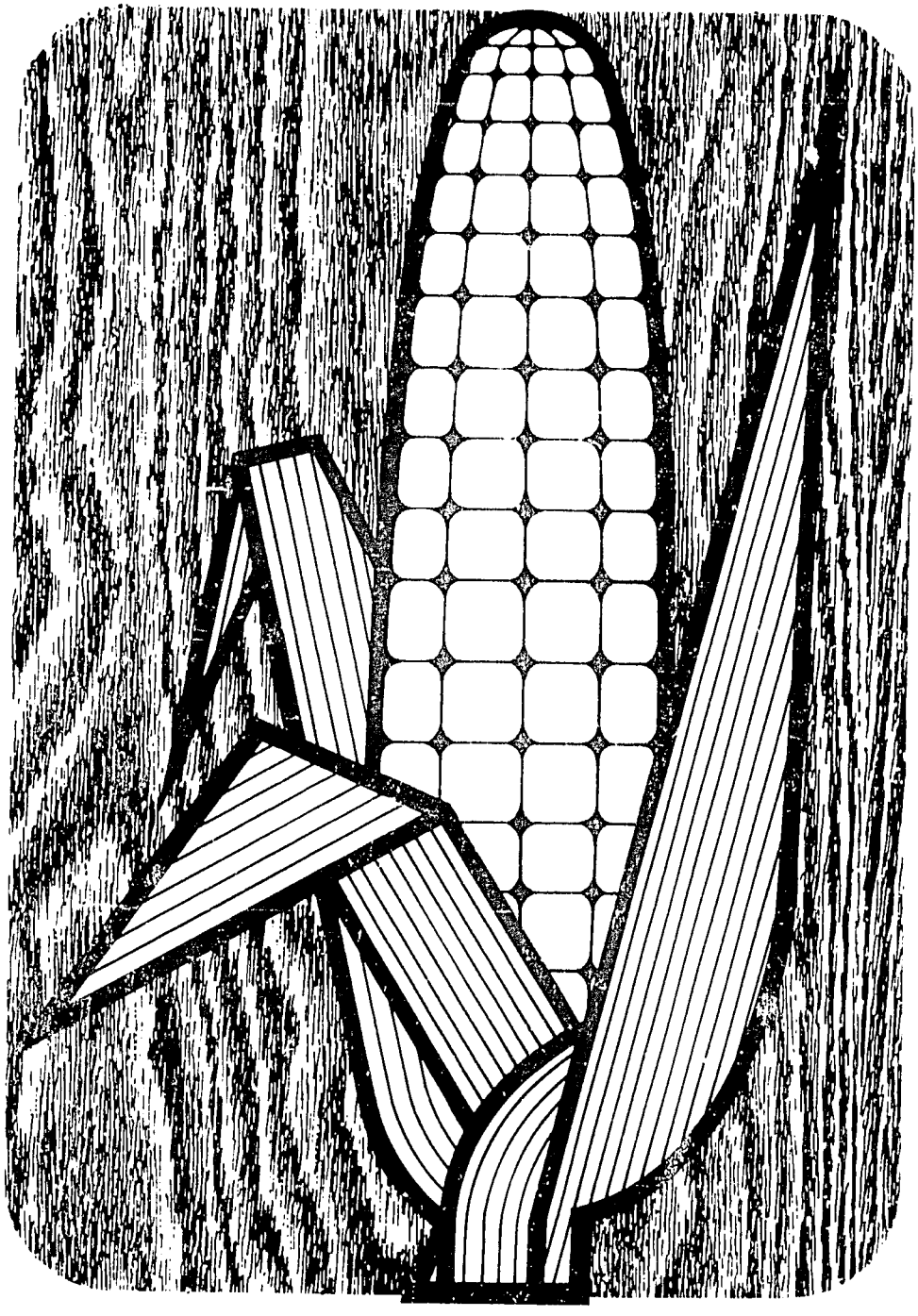

WEED CONTROL IN MEXICO

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INTRODUCTION

Mexico offers great diversity of agroecological areas, and equally diverse is the technology used in them. Thus, we find highly technified and high-yielding farmland in the north, rainfed agriculture in the central high valleys with mostly small farmers, and tropical farming in the south where the small farmers also prevail.

Our experience is mainly related to the rainfed farming in the high plateau of Mexico, where most of the farms average 2 to 4 ha. However, we have also had several opportunities to visit the tropical south. Small farmers, whether in the rainfed central valleys or in the tropics, face many of the same problems. Therefore, our comments in this paper will focus on the small farmers, with particular reference to the high valleys of Mexico (Fig. 1).

SOME CHARACTERISTICS OF THE SMALL FARMING SYSTEMS

Small farming is primarily subsistence oriented, employs family labour, has a low cash turnover, and consequently, also low levels of farming inputs.

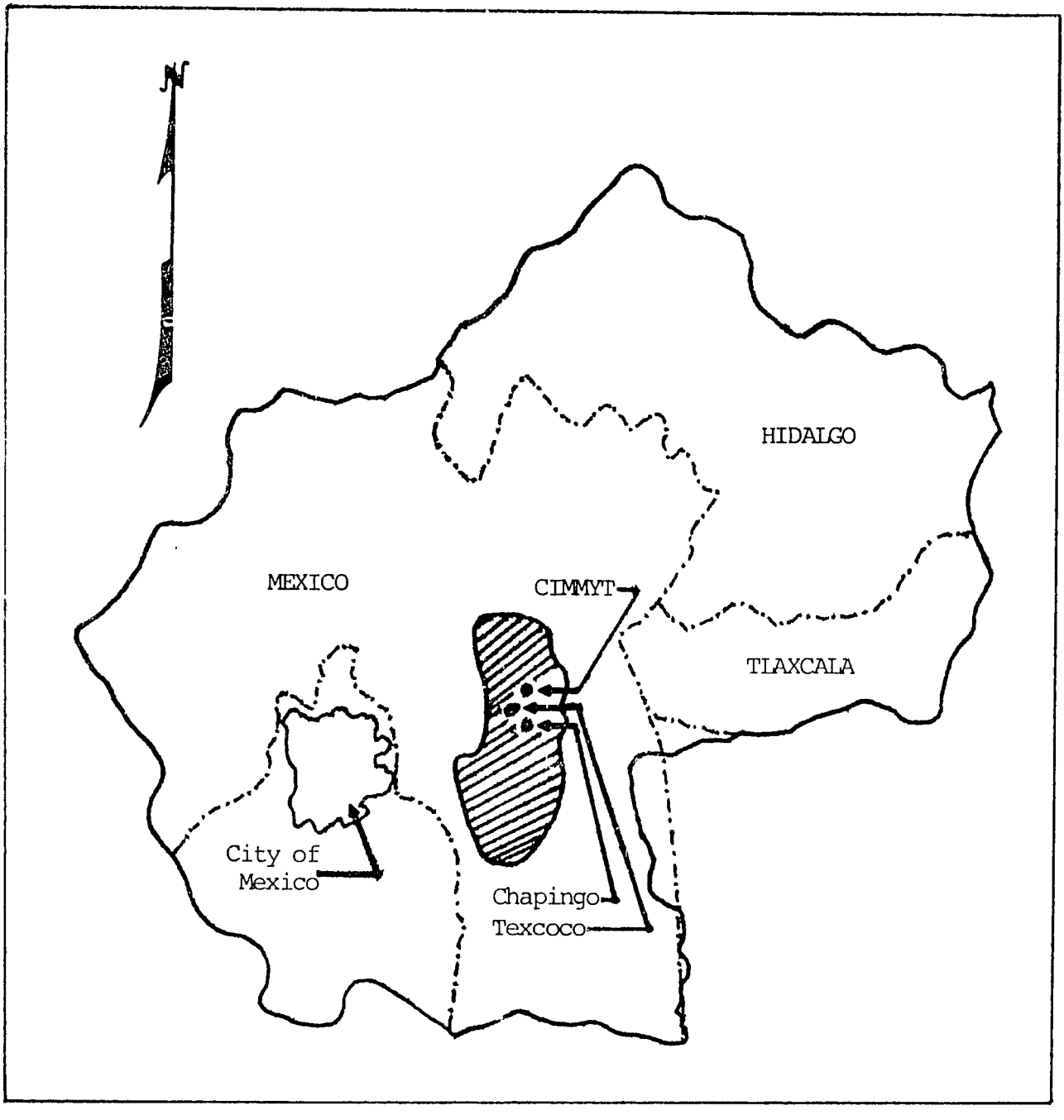

Figure 1. Chapingo and surrounding States in the Valley of Mexico.

Our area of work is within the range of influence of the University of Chapingo, Mexico. The altitude is 2,250 meters above sea level. The climate is sub-humid with an average yearly rainfall of 645 mm (528 mm from May to September) and winter drought; average yearly temperature is 15° C.

In the Chapingo area, farming mostly takes place during the rainy season ("temporal"), which provides an average rainfall of 528 mm from May through September. Only those growers that can afford irrigation grow crops in the dry season.

Hand labour and animal-drawn cultivation are the prevalent weeding practices. Many farmers use knapsack sprayers for disease and insect control, but their use to apply herbicides is very limited. Larger farmers (>50 ha) are mechanized and some have tractor-mounted spraying units. Their services may be contracted by the small farmer.

The smaller farms tend to be more diversified, while the larger ones tend to concentrate on one or two crops (Fig.2). In the central valley of Mexico, the major crops are maize and beans intercropped, plus barley and alfalfa for hay.

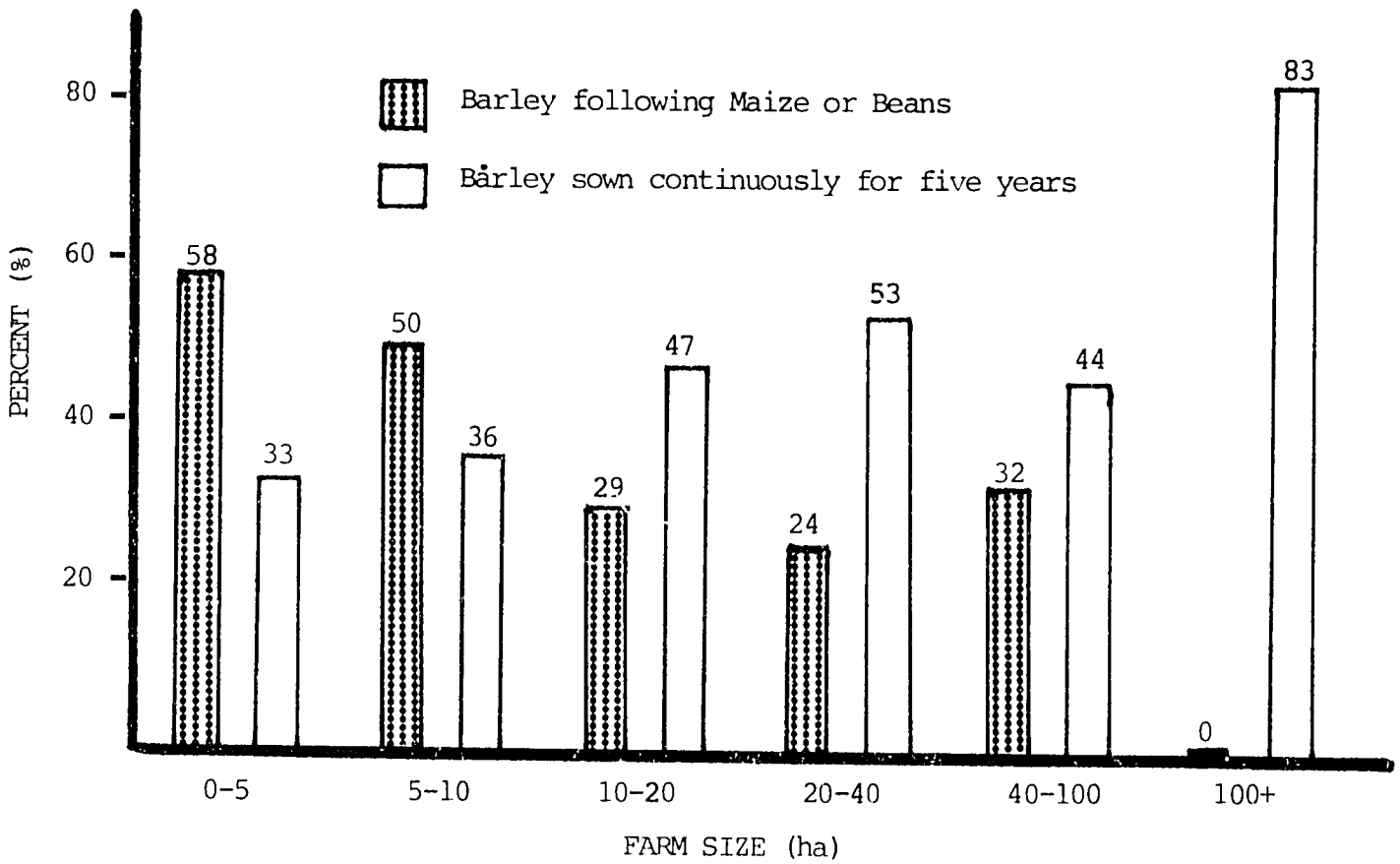

Figure 2. Percentage of farmers in the barley areas who are using two different rotations, by farm size (4).

Repeated cultivations (either mechanical or by hand) are the principal means of weed control in maize and beans. Some larger farmers may use atrazine in maize. For beans, the official recommendation is dinoseb (alkanolamine salt) as a preemergent herbicide. However, we believe the use of this herbicide to be very restricted, and furthermore, it was recently dropped from the market. We have also found that the residual activity of this compound can be too short to be effective in our light soils when heavy rains occur. Also, this is a highly toxic material which can be very hazardous in the hands of an unexperienced or illiterate farmer.

The intercropping of maize and beans, sometimes even including other crops such as squash, is very popular and 20% of the maize in Mexico is grown in a mixture with other crops (12). The farmers find a higher income stability with this system. Lepiz (13) found a Land Equivalent Ratio > 1, which indicates that it would take more than one hectare of pure stands of maize and beans to obtain what is produced in one hectare of intercropped cultures. Mixed crops are also more competitive with weeds (12). Cultivation and hand weeding are the prevalent weed control measures in the intercropped situation.

Alfalfa is grown for hay. It is planted at the end of autumn to avoid serious weed problems. It establishes slowly during winter, and in spring it grows together with the great flush of weeds of that season. Thus a whole season (winter) remains virtually unproductive. The first clipping in spring is the only weed control practice employed. Farmers do not use herbicides in alfalfa.

Barley is mainly grown in areas where the risk of frost and lower rainfall make the maize cropping inconvenient. The use of 2,4-D is quite widespread among these farmers. The on-farm training and research programme of CIMMYT (International Center for Maize and Wheat Improvement) has had an important impact in promoting the use of herbicides, fertilizers, and improved varieties among these farmers.

WEED CONTROL AND OTHER LIMITATIONS TO IMPROVED FARMING

Land tenure and general crop management are the main technical limitations to agricultural production in small farm areas. Educational deficiencies and lack of good roads and basic services are very often additional disadvantages the peasant farmer must face.

Small farm holdings do not allow the build-up of capital necessary to increase the level of farming inputs conducting to higher yields. This is an entirely political issue and governmental action is needed to improve this situation.

In respect to crop management, one of the deficiencies is an excess of tillage operations. To plant maize, a farmer will plough, harrow, and then ridge the soil surface. Four to five seeds are deposited at the bottom of the ridge, every 50 cm. Ridges (crop rows) are 90 cm apart to allow the passage of cultivating implements. Twenty days after emergence, the crop is cultivated to control weeds and accumulate earth at the base of the plant. Forty to 50 days after emergence, a second cultivation follows. Some farmers apply fertilizer with this last cultivation. The use of fertilizers is quite erratic however, or at least most of the farmers are unaware of their composition (4).

In the case of beans, cultivation and weeding are done by hand. This excess in tillage not only poses a risk for soil conservation (expecially on sloping lands, and heavy showers during the rainy season) but also means a considerable amount of time and energy spent to control weeds. Cultivation can also damage the crop considerably; particularly if heavy rains force late operations and horses are used to pull the cultivator through an already fairly developed crop.

Weed control is the crop management aspect that currently claims highest attention. Though weeds pose a serious threat to the crops in central and southern Mexico, information available to the farmer is very scarce, except for the individual efforts of the chemical companies which may overemphasize the use of herbicides. Official recommendations are scarce and very often quite outdated.

The farmer has learnt to live with the weeds, adopting a sort of fatalistic attitude, rather than being able to keep them in check. By this we mean that several of the main problem weeds (Amaranthus spp; Portulaca oleracea; etc.) may have become part of the peasant's diet, perhaps due to his inability to eradicate them. Yield reduction due to weeds is impressive (Table 1).

Table 1. Effect of Weed Interference and Weeding Practices Upon the Yields Rainfed Corn and Barley

crop	grain yield reduction in a weedy crop	grain yield reduction when a conventional weed control technique is used
	(%)	
Corn (intercropped with beans)	99	No data
Corn	88	34*
Barley (1979)	22	0**
Barley (1980)	43	10**
Beans	79	31*

Source: Fischer, A.J., 1981. Consideraciones Ecologicas para el Control de Malezas. Texto de la Conferencia dictada para el Curso Intensivo de Agroecologia. Enero-Febrero 1981; Depto. Fitotecnia, Univ. Autonoma Chapingo, Dept. de Parasitologia.

* Two cultivations, 20 and 40 days after emergence; **Standard treatment with 2,4-D.

Hand labour and mechanical (or animal drawn) methods are almost the universal means of controlling weeds (except for the previously mentioned barley growers). Hand labour is so slow that it seldom allows a timely elimination of the weeds. The critical period of weed competition in corn and beans, as well as for the intercropping of those species, has been established (1,3,15,16) and occurs within the first 30 to 40 days of the crop's growth. However, weeds are generally not controlled until 20 to 25 days after emergence with the first cultivation. A great deal of the yield potential has by then been lost to the weeds. Rains very often delay the cultivations, making this situation worse. On the other hand, if weeds were effectively controlled during those first days of the cycle, the usual cultivation at 40 to 50 days after emergence would not

be necessary, since the crop will by then dominate the weeds, provided a good stand exists.

When the machete is used for weeding, the weeds have to reach a certain height to be grabbed and cut; this usually happens 20 days after emergence. This cutting takes one person a week to clean one hectare. If one farmer has 10 ha he can only use 3 to 4 ha, because by the time he finishes cutting the weeds in those 3 to 4 ha, the crop will be already lost by weed interference on the rest of his farm (17).

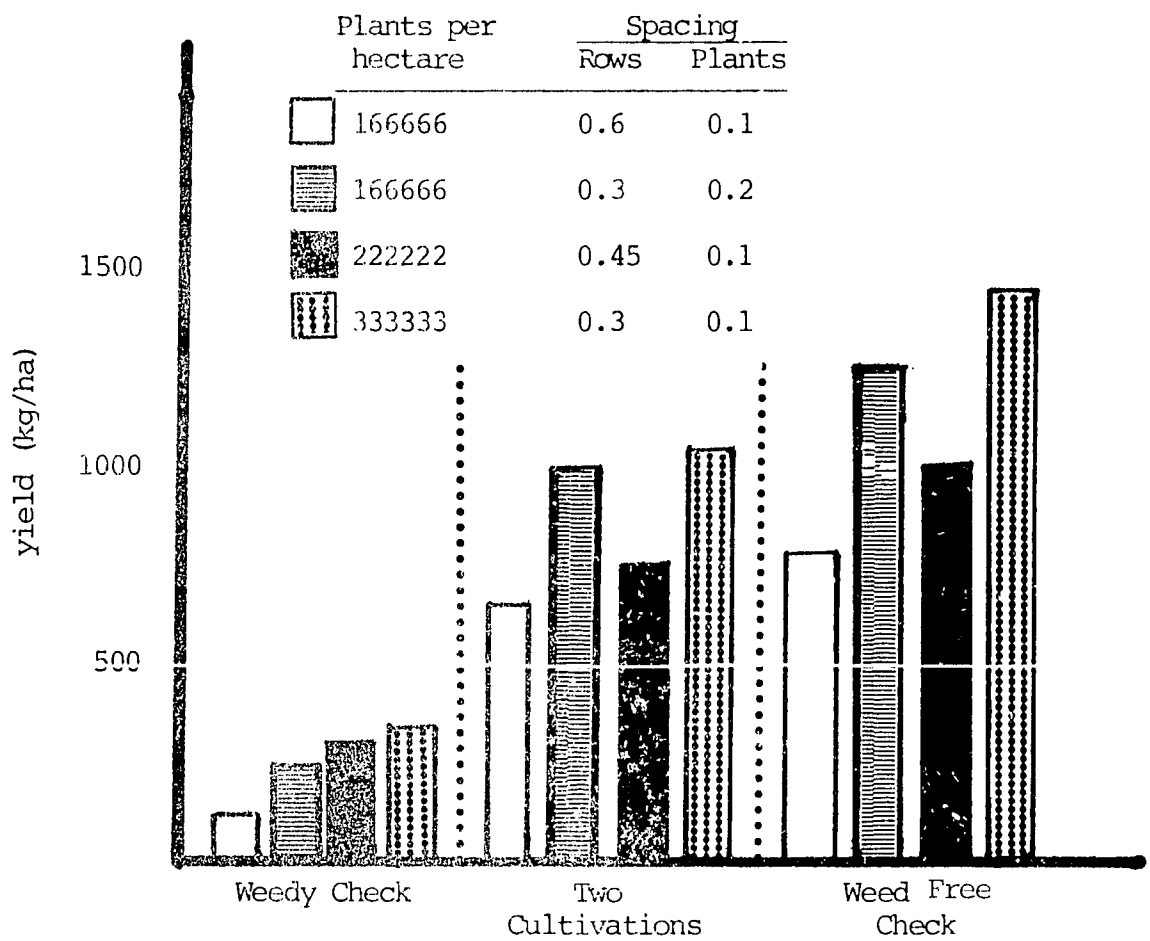

Figure 3. Effect of plant density and distribution on the yield of beans under varying weediness (12).

Hand hoeing is slow, painful and often unhealthy. The passage of machinery compacts the soil and pulverizes the surface, increasing the erosion problems. Horses and oxen often tread and damage crop plants. Weeds within the row are usually poorly controlled.

In order to allow for physical or mechanical weed control practices, crops have to be grown in wide rows, not benefitting from the potential yield increases obtained under narrower rows and higher densities, with the water supply of the rainy season (Fig. 3).

New technology should provide higher yields, less effort, and additional time to work off the farm and have a better income, or increase the amount of land to be farmed by the same family (17, 11).

PROPOSED MANAGEMENT ALTERNATIVES

The research activities in weed science at the University of Chapingo, Dept. of Plant Parasitology, focus on a systems approach to manage the weed problems of the small farmers.

The introduction of herbicides, reduced tillage (Table 2), modifications in seeding rates, and plant distribution (Fig. 3), have shown promising benefits, especially if residual herbicides avoid the need of wide row spacing for cultivating. The rationalization of fertilizer use and a better understanding of symbiotic-N fixation have proved effective in avoiding excessive weed growth by favoring the competitive ability of the crop.

Table 2. Grain Yields of Maize Using Herbicides and Different Tillage Operations

treatment	planted on flat ground & no further tillage	soil surface ridged & no further tillage	ridged + 1 culti-vation.	ridged + 2 culti-vations.
	(kg/ha)			
Atrazine + alachlor (pre-emergence)	2507	1869	2112	2475
No herbicide	0	562	644	1058

Source: A.J. Fischer et al.

Competition experiments (1, 3, 15, 16) have given a better idea of the "critical periods" during the growth cycle of the crop in which interference by weeds occurs. The crop has to be free of weeds during the critical period in order to obtain maximum yields. The farmers thus should know when to start and when to stop weeding, how to use the competitive ability of their crops to suppress weed growth, and avoid excessive labour and tillage in eliminating weeds when they are no longer detrimental to the yields.

Alfalfa can be planted in spring if herbicides are used for a safe establishment. The preceding winter can thus be used to grow a winter crop to make a profit during that season, which would otherwise remain virtually unproductive under the traditional management.

Other alternatives proposed for weed management are:

- establishment of a rotation programme including legume forages, thus lowering the need for nitrogen fertilizers if the legumes are adequately inoculated with efficient Rhizobium strains;

- current efforts to improve the status of symbiotic-N fixation in crops such as beans (5), should lead to the use of this process as a way of selectively supplying nitrogen to the crop and not to the weeds. Since high levels of mineral nitrogen are known to inhibit nodulation by Rhizobium and nitrogen fixation (10), application of nitrogen fertilizers to these legume crops should seek to complement, but not to inhibit symbiotic-N fixation;

- the equipment and the techniques of herbicide application should be adapted to the needs and means of the small farmer. Spraying equipment is often too expensive for the subsistence farmer in relation to the cash returns he can expect from his crops, even if yields are increased by its use (14). The manual operation of current hydraulic knapsack equipment is arduous, and very often seems to be the only way small farmers can use herbicides. Some alternatives have been proposed, such as the use of granular formulations in order to avoid purchasing spraying equipment (11). Dawson (6) has shown the possibility of using herbicide-treated seed which allows planting

and applying herbicide in one operation. Manual planters, such as early American farmers have used, could be adapted to apply seed and granules in one operation, or be used to plant herbicide-treated seed. These planters could become efficient no-till seeding equipment. The small farmers currently use a spade or sharp stick to open a hole in the ground where the seed is deposited and covered with the foot. With these methods, cultivation would still be needed to weed between the rows, but good weed control within the rows will ensure safe crop establishment. Reduced, or no-till operations need not be based only upon sophisticated or inaccessible equipment;

- reduced volume spraying and controlled droplet application will definitely have a place in areas where water is scarce or its transportation difficult. Progress is being made in order to adapt such equipment to the working conditions of the peasant farmer (9). Hand-held rope wick applicators will be very helpful for selective postemergent control and in the management of perennial weeds;

- herbicide screening should aim at finding compounds with a wide safety spectrum for use in several crops. The ideal situation would be to use just one product for most situations. Even if only major weeds were controlled, the current weed infestations would be significantly lowered within the critical periods (11).

All these proposals may be effective if complemented by improved crop management in other areas such as crop varieties, integrated plant protection measures, fertilizer use, etc.

DIFFICULTIES TO TRANSFER MORE EFFICIENT WEED MANAGEMENT TECHNOLOGIES TO THE FARMER

The farmer is usually more aware of the losses due to insects and diseases than those due to weeds.

Not always is the farmer interested in higher yields per hectare. Rather, he strives for minimum risk and sufficient production to feed himself, his

family, and the animals on his farm. The peasant farmer will be reluctant to incorporate non-traditional practices which may also demand more cash expense and therefore seem more risky.

In some cases, illiteracy does not allow the farmer to understand extension bulletins (if they reach him at all).

Less labor-intensive weed control measures may create unemployment in certain areas. However, we do not think this is a prevailing situation.

The farmer may not always have enough cash available to purchase new products or equipment. Credit is available however, and the farmer should be made aware of this situation and advised for an adequate use of that money.

Farmers grow a diversity of crops, very often intercropped, which makes the use of herbicides more difficult. However, as we have said before, improved weed control on small farms is a vegetation management situation, where herbicides should only be one of the many tools to be considered.

Communication of research among scientists has traditionally been deficient. There is an obvious gap between those who generate the technology, or have the "know how," and the peasant farmer. This gap must be traced to the areas of research, extension, and teaching in weed science.

Research can often be academic rather than practical, looking into rather sophisticated aspects and leaving field problems unsolved.

A systems, or vegetation management, approach is not always used in weed research, perhaps because weed research is not always oriented towards the small farmers. The national research institute in Mexico has a weed research programme. The results of their work need to be published and diffused; these have been, so far, poorly known. The communication gap between the diverse institutions involved in weed research activities has lead to the duplication of efforts while several areas have remained unattended.

Researchers are not always fully aware of the weed or management problems the farmer faces. More on-farm research should help close this gap and also serve demonstrative purposes. CIMMYT, with its on-farm training and research programmes, and the Department of Parasitology at the University of Chapingo, with a high percentage of its weed experiments carried out on farmers' fields, have already moved in this direction.

There is a national extension programme within the State Department of Agriculture (SARH). The Plant Protection Division, also within the SARH, also has an extension branch with plant protection scientists. The general feeling seems to be that these programmes need to be motivated to effectively reach the farmer. It is typical to see good husbandry and high yields within experimental fields, and poor levels of crop production on nearby farms. The plant protection scientists have had an exposure to weed science during their career, but there are no full-time weed scientists in extension. Except for the plant protection personnel, the extensionists in the national programme have little or no training in weed science.

Extension should be responsible for making the farmers aware of the losses due to weeds and of the management alternatives they can use to face this problem. Extensionists should help the farmer make advantageous use of the credit facilities, which otherwise tend to be largely misused.

We believe that all institutions teaching agricultural sciences should include a compulsory course on weed science. In addition, institutions with already trained weed scientists should sponsor short courses to provide good practical training and sufficient theory in weed science to extensionists and fieldmen in general. Industry has an excellent opportunity to contribute in this aspect.

RECENT PROGRESS

The status of weed science in Mexico has improved considerably during the last year. This has been mainly due to the revival of the Mexican Weed Science Society (SOMECIMA) which has already sponsored national meetings in 1980, '81, and '82. Industry and official institutions have had active participation in

these events. The 1981 meeting was held at, and organized by, the Parasitology Department of the University Chapingo, Mexico.

In the Dept. of Parasitology, Univ. of Chapingo, there are five full-time weed scientists engaged in teaching and research. Three hundred undergraduate students take a one semester course on weed science each year. Together with scientists from other institutions, Chapingo has offered short courses to extensionists and fieldmen of private and public institutions. In due course, Chapingo will implement graduate level weed science training.

Weed science teaching in Mexico was positively stimulated since the Weed Science Teaching sessions at the 1981 SOMECIMA meeting in Torreon, Mexico. At that time, teaching programmes were discussed, and the role of universities in research assessed. Since then, other institutions have become more active in weed science teaching; teachers from Chapingo have often been invited to lecture at other national universities. The Instituto Tecnologico de Monterrey has also been active in weed science teaching and research.

The weed research programme at Chapingo began to work actively in 1979, and since then has distributed its research reports to other scientists in Mexico. We hope that other institutions will also feel stimulated to publish and distribute the results of their efforts. This would be a great contribution towards the exchange of knowledge among scientists and would help provide updated recommendations to the farmers.

The current efforts to boost weed science in Mexico must assign greater importance to activities in the tropical areas and inject new life in the tropical weed research programmes. There it is very common to find an agronomist at an experiment station in charge of the management and breeding of several crops at the same time, and in most cases without adequate training in weed science research techniques.

The University of Chapingo has regional centers in different agroecological areas of Mexico. It is hoped that weed scientists, after completing their basic training at Chapingo, will be sent to those outposts to work on local problems.

If the current trend of effort continues, we foresee a promising future for weed science in Mexico.

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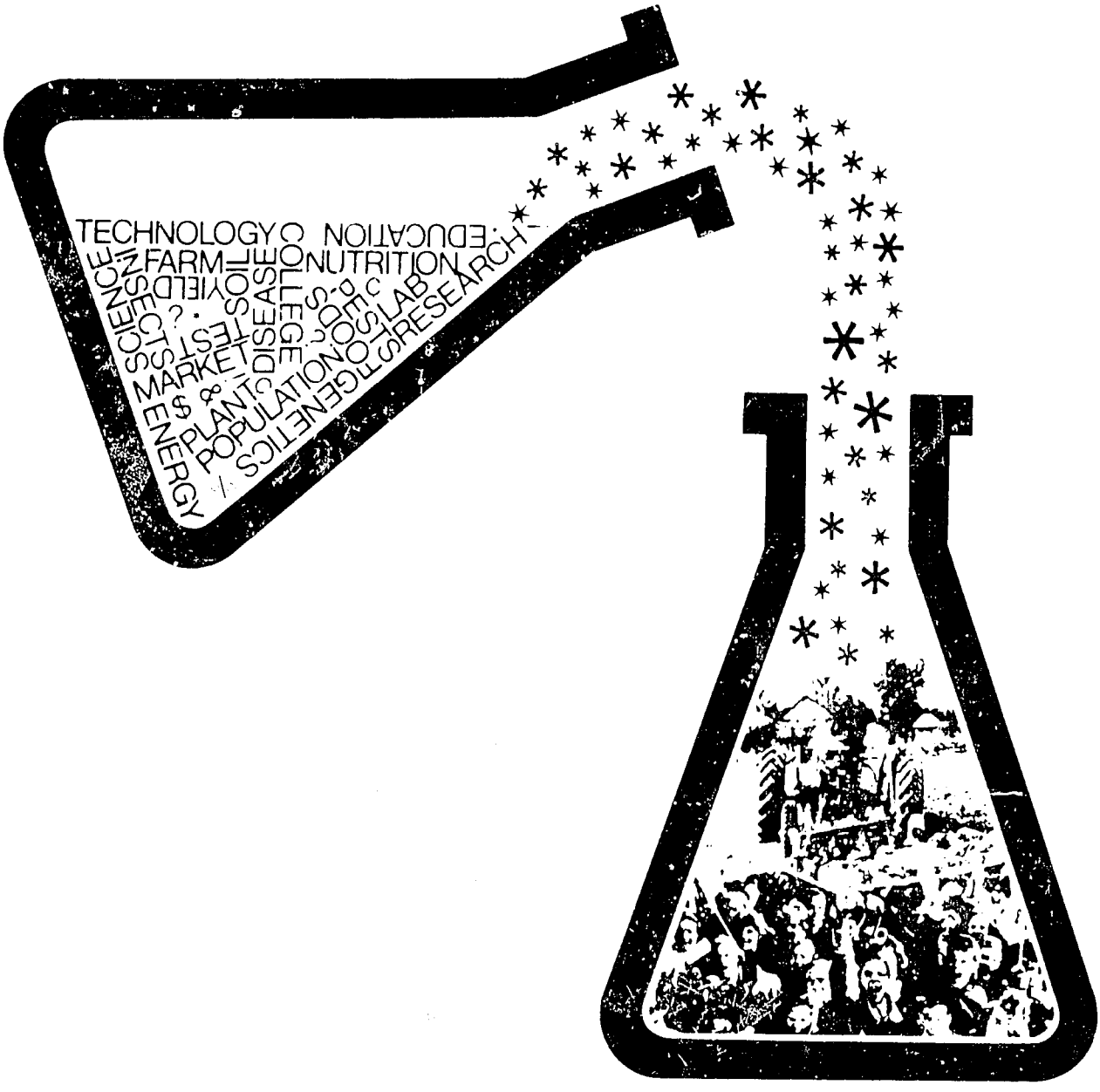
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TECHNOLOGY TRANSFER--SOME STRATEGIC SOCIAL ORGANIZATIONAL CONSIDERATIONS WITH APPLICATION TO WEED SCIENCE

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INTRODUCTION

Technology is inherently social because it consists of standardized operations by which users expect to obtain predetermined results. Such procedures require that people organize effectively to implement them according to design specifications. Failure to organize in appropriate fashion for the use of a technology is a major obstacle to its successful transfer. The technologies of weed control specify requirements for human behavior which must be fulfilled if that objective is to be attained. Improved weed control technology is of critical importance, depending upon specific local conditions, because much of the farmers' time is consumed in weed control efforts. It has been proposed that "... more energy is expended for the weeding of man's crops than for any other single human task" (4). The land a small farmer can plant may be limited to the land that one can weed (6).

When weeds are effectively and appropriately controlled, it is because people have organized decision systems capable of diagnosing weed threats, allocating labor and technical resources to the control of those threats, resolving priority conflicts among the threats, and regulating the technologies so as to minimize external repercussions among the community of farmers. Therefore, when one introduces a new weed control technology, one is transferring not simply a physical item, but a new pattern of behavioral expectations which must

be incorporated in the host social system. Such behavioral expectations have organizational implications. It is the purpose of this analysis to examine two properties of technology which have major implications for social organization and the technology transfer process, and to apply the analysis to the domain of weed science.

TECHNOLOGY AND SOCIAL ORGANIZATION--AN ANALYSIS

Six types of technology are distinguished on two strategic dimensions (2). First, the dimension of divisibility--a technological good is said to be divisible if it can be utilized productively in "small" units as well as large. This is to say that productivity of the good is insensitive to scale. For example, seeds, fertilizer, and herbicides are highly divisible because farmers with varying amounts of cultivatable land can utilize whatever amounts of those inputs they require. An indivisible good, on the other hand, is lumpy in nature--units of some substantial minimum size are required with no possibility of subdividing as in the case of large pieces of machinery or, in the extreme, large hydro-electric or nuclear power projects with associated electrical grids. Interest in "fractional" technology has to do with making relatively lumpy technologies more divisible by shrinking their scale as in mini-pumps, scaled-down tractors, backpack sprayers, and the like. It is worth noting at this point that weed control chemicals, by nature, are highly divisible, although they may not be marketed as such.

The second dimension is that of collective versus private goods. A technological good is said to be private if its major benefits can be captured by the investor and be denied to those members of the community who do not invest in it (1, 3, 5, 7). A collective good is one, the significant benefit of which cannot be denied to those who do not help bear the costs--the free riders. For example, if chemical residues should contaminate an irrigation canal serving a community of farmers and thereby impose a cost upon all farmers in the form of reduced crop stands, and a decline in yields, an investment in cleaning up the water by a few will confer a benefit upon all. If one should make an investment of time, energy, and money to improve the water quality, the benefits cannot be captured by the single investor who determines that it is rational to wait for others to undertake the investment. If each of three farmers suffers a $40 loss

of production and if remedial action would cost $60, no single farmer will find it in his interest to clean up the residue. Yet the $60 cost is clearly less than the gain to the three-member community--namely $120. Yet, each rational decision-maker finds it in his interest to be the "free rider" on the investment of others and nothing will be done--unless there is a social organization available to insure that each pays an equitable share. The public goods situation can only be mitigated by the presence of social organization with sanctions to control free riders so that each contributor will be assured that each other beneficiary will contribute.

These two analytical dimensions of technology, although continuous, can be broken and combined into a six-fold matrix (Table 1).

Table 1. Six Types of Technology

type of good	divisibility: high	medium	low
Private	Cell One	Cell Two	Cell Three
	seeds, fertilizers, herbicides, pesticides.	large tank sprayers, tractors.	centralized production of private products.
Public/ Collective	Cell Four	Cell Five	Cell Six
	sub-community control of weed threat or herbicide residues.	community control of weed threat or herbicide residues.	centralized control of weed threat or herbicide use.
	sector of small sub-community organization.	sector of community organization	sector of large scale public enterprise.

Cell one. High divisibility of technology is combined with private goods in this cell. Although small farmers tend to lag behind larger operators

in adopting these kinds of technology, smaller farmers can and do respond to economic incentives to adopt them whenever they are: 1.) aware of them; 2.) reasonably certain of their efficacy; 3.) able to secure necessary credit and technical assistance; and 4.) able to locate sufficient supply such that more powerful operators do not utilize all of what is available. Herbicides clearly fall into this category.

If technologies of this type can be demonstrated to have good cost-benefit ratios and if risks are manageable, chances are that the herbicide technologies can be diffused through the marketplace. The required analysis here is that of demonstrating technical and economic feasibility combined with sociological and extension work to determine that the marketplace is functioning with appropriate information.

Cell two. This sector presents moderately divisible technologies of a private type. The economic man model applies here only for larger operators who have access to the capital and credit to make purchases of items such as large units of farm machinery. Large estates for the production of sugar, tea, coffee, and rubber provide examples (6). Herbicides, by nature, do not belong in this category unless we force them here by the manner in which they are packaged and distributed.

The question becomes: are there weed control technologies too lumpy to be adopted by smaller operators? If so, what are the obstacles to breaking them down into smaller, more divisible units that characterize cell one? Are there safety or other reasons for application of herbicides only with moderately lumpy equipment? If so, smaller operators will have to be served by small-scale private cooperatives or mutual companies which can purchase and maintain such technologies, and develop the specialized skills for handling them since, as Parker (6) notes, most of the conventional selective herbicides for annual crops do not have adequate safety margins for use by uneducated farmers.

Cell three. Representing a combination of technologies of low divisibility but of a private nature, this sector is exemplified by centralized factories for producing herbicides. These chemicals may well be divisible in actual field

application, but the production technologies can be expected to be highly lumpy. Still, the investor obtains the returns and the free rider can be easily controlled. The organizational problems of this sector are traditionally defined by industrial sociology--how to organize the work process such that it is integrated well with the needs and perceptions of the work force. At the level of the over-all industry, the problems are typically those of the state's willingness to provide adequate incentives for production and distribution of the product. Assuming these incentives exist, problems of technology transfer center on training the work force, licensing agreements, securing credit, and the like.

Cell four. Here one finds a combination of collective goods which are relatively divisible. Since individuals who are rational will not find it in their interest to invest in projects which produce major benefits for the free riding noninvestors, some social organizational structure must exist to ensure that recipients of benefits will also pay an acceptable share of the costs. Such organizational structures are to be found in small organizations limited to subunits of the local community who share a particular weed control problem. For example, if application of a given herbicide should result in residues carried by irrigation tailwater into neighboring fields and thereby interfere with crop production, the particular subset of affected farmers can organize to enforce rules for herbicide application so as to minimize the generation of external damages. The sociological problem is how to sustain conditions for small-scale subcommunity organizations for such purposes.

Cell five. This sector contains those collective goods technologies which are only moderately divisible. There may be weed threats to the community of farmers which cannot be adequately addressed by one or a few farmers alone. In effect, many farmers in the community must actively engage in controlling such threats to production. For example, local irrigation water courses serving local communities of farmers become infested with weeds such that delivery efficiencies are drastically reduced. If one farmer should spend energy and money necessary to clear the fraction which passes his land, his contribution to increased water delivery is so negligible as to make his investment unproductive. Efforts of the few will be overwhelmed by negligence on the part of the many. Here organizations must collect resources from the many and apply

weed control technologies to the entire watercourse system to sustain crop production.

Individuals will not invest in this kind of technology because if any one should make an investment and many others do not, then the single contribution comes to naught. If, on the other hand, many others through some irrational altruistic spirit make the investment and he does not, the project will be completed without his relatively negligible contribution and he will benefit from the community's work. Transfer of weed control technologies for such collective purposes necessarily entails construction of a disciplining social organization.

Cell six. This sector represents highly indivisible technologies that are public or collective in nature. If any single technologically related discipline can be associated with this cell, it would be civil engineering. A great share of the products of civil engineering--dams, barrages, large canals, bridges, roads, and electrical grids--cannot be purchased by individuals, private organizations, or public organizations of modest scale, but must be purchased and maintained by large-scale public organizations which can capture the costs from socially diverse and geographically widespread benefiting groups.

In the domain of weed control, technologies enter this cell in the senses that: 1.) the public sector must insure, at the national and international levels, proper handling and application of these materials through regulation and enforcement, information dissemination, and formal education of skilled expertise capable of performing weed control research and product evaluation; and 2.) specific weed control tasks can only be performed in large units (e.g., irrigation networks) beyond the capacity of local organizations.

Certain rules for packaging, labeling, and applying specified herbicides must discipline marketplace exchange to ensure the health and wellbeing of the populace, and to promote long term ecological stability of farming systems (8). Furthermore, large-scale public organizations must conduct large-scale weed control efforts over sizable land and water units, such as livestock grazing ranges or large-scale irrigation networks. Technology transfer, for these purposes, requires that large-scale public organizations develop the skill to

manage these tasks with care and sensitivity. Those who would wish to involve themselves in such technology transfers must involve themselves in the affairs of large-scale bureaucracies.

CONCLUSION

In sum, it is suggested that the constituent technologies of weed control can be usefully divided into six mutually exclusive categories. Each category represents a unique combination of properties which, it is asserted, affect adoption and utilization of the technologies involved. Each type of technology implies a different organizational problem to be addressed in technology transfer.

If weed control problems can be addressed by private and divisible technologies of cell one, the transfer problems appear in their simplest form. The analytical problem is to insure that the technological packages are attractive from a benefit-cost standpoint and to address problems of target group awareness. If functioning marketplaces do not exist for the distribution of these technologies, they must be built; there may be need to overcome the problems associated with maldistribution of social and economic power which operate to undercut small farmer participation in the marketplace.

If weed control problems are those of cell two, the focus can still be largely economic for large operators who can deal with the moderately lumpy control problems they face, but the focus of technology transfer must be on construction of appropriately scaled private organizations for smaller operators who can thereby join in common effort to provide the moderately lumpy good and keep noninvestors from enjoying the fruits of their investment.

If one sees cell three weed control problems, the appropriate response would be to ferret out the economic problems preventing private firms from supplying necessary inputs to farmers--individually or collectively. The technology transfer problems become those of internal firm organization which affect productivity or those constraints to transfer occurring between state and firm affecting the firm's incentive to produce.

If problems are those of cell four, the technology transfer task is to design ways to create local small-scale organizations which can provide collective goods to subcommunity units. No matter how technologically feasible or economically attractive, these weed control technologies will not be employed to achieve the goals intended if small units of farmers cannot work out ways to overcome the negative repercussions of local misapplication of weed control technologies which become the basis for community dissension and mutual sabotage. The technology transfer task here is to comprehend the existing local organizations and to determine feasible ways of harnessing such organizations to the objective of sustaining the needed small-scale but essentially public control technology.

If problems center around cell five, the analytical problem is to design larger community level organizations to provide collective goods for the appropriate area. Failure to control a persistent weed in one subarea can lead to its rapid spread to another adjacent area, and to the next. The transfer problem is a larger version of that found in cell four.

If one views the weed control problem to be that of cell six, the task is to investigate problems of intra-and inter-bureaucratic relationships and the linkages of large-scale regional or national bureaucracies to local organizations. Problems viewed at the local level may well be an outcome of deficiencies in market regulation that can only be performed by central public authority.

Weed control projects can encounter difficulties associated with any one cell or any combination of cells. The tasks of sociological analysis of weed control technology must differ significantly as the diagnosis of the technology transfer problem shifts from cell to cell. Furthermore, any given weed science technology takes on a different character at different points in its production and use. A herbicide may well generate a cell three problem at the production stage, a cell two problem in the distribution stage, a cell one problem if small operators cannot obtain it on local marketplaces, a cell four problem after it has been applied in the field, and a cell five problem if an insufficient proportion of the community employs it appropriately, and a cell six problem if it is being mispackaged or mislabeled on provincial or national scale. The problem

is to diagnose the strategic weed control problem constraining production, then to devise a research-action program to relax those constraints. If social organizational factors are left unanalyzed, then there is real risk that attempts to transfer weed control technology will be unsuccessful.

ACKNOWLEDGEMENT

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WEED SCIENCE TECHNOLOGY COMMUNICATIONS: THE NEEDS OF RESEARCHERS IN DEVELOPING COUNTRIES

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INTRODUCTION

Both authors have experience in developing countries, but in different continents. It became obvious soon after they were asked to write a joint paper that developing countries are a very heterogeneous group. Some have no trained weed scientists, others have only one working in comparative isolation, while others have flourishing weed science societies.

Despite such differences, it has been possible to identify important common features which widely limit communication of weed science technology. These will be described first and then followed by suggested ways in which such limitations may be eased.

CHARACTERISTICS OF DEVELOPING COUNTRIES

Restricted staff. Many countries have a shortage of professional weed science staff and where they do exist they often have to work in comparative isolation because there is little likelihood of there being another professional of the

same discipline in the area, or even within hundreds of miles. The resulting lack of inspiration and stimulation to be had from fellow weed scientists is a significant handicap. This handicap is enhanced by the inevitable gaps in allied professions such as plant physiology, taxonomy, biometrics, ecology and soil science. Similarly, there is a shortage of skilled technicians. Unskilled labour is usually plentiful, but skilled work will often have to be done by the professional until such time as someone else can be taught to do each particular task.

Most of our countries lack an effective teaching, research, and extension triangle. In weed science this is aggravated by the fact that rather few agricultural schools offer a course in weed science. Therefore, a great number of professionals involved in weed management situations have limited training in this discipline. We have few extension agents and very few of them have a full time commitment to weed science technology transfer. In general, teachers and extension agents are insufficiently aware of the progress of research.

Limited facilities. Supplies and equipment of all kinds, workshop and library facilities, and sometimes finance, are in much shorter supply than in developed countries. In many cases, one can improvise but this is hardly possible in the case of an inadequate library. The specialist journal is the most important contact that the developing country weed scientist has with the mainstream of weed research elsewhere in the world.

In 1977, the Agricultural Department Library in Zambia subscribed to 380 journals. But in 1981 the allocation of money for journals was zero. This was due to a shortage of government funds in general and an acute shortage of foreign exchange. The latter depends very largely on the world price of copper, the principal export, which has declined in real terms over recent years. This elimination of funds for periodicals has caused the number of journals received to decline to 95 in 1982. These 95 were those available free or in exchange for Zambian publications, and did not include the three weed science journals which had been formerly subscribed to.

What has been said about journals applies also to books. The lack of periodicals reduces the chance of seeing reviews and announcements of new books,

and those one sees require foreign exchange to purchase. The problem is less acute for the expatriate worker paid in external currency. He can order books from overseas, though if they come by air, the cost may be doubled for the more distant countries.

Training. Most developing countries have a University, but in countries with a small population such as Zambia (6 million) or Uruguay (3 million) the range of courses offered is necessarily limited and neither of these two offer weed science courses. Indeed, the subject hardly appears within their agricultural syllabuses. In contrast, Mexico, with a population of 72 million, has at least two active University weed science teaching and research programmes.

Help from overseas. A number of overseas institutions provide valuable help, usually in the field of publications, to the developing country weed scientist. Both authors have been impressed with the flow of information from the International Plant Protection Center at Oregon State University. This service, through their INFOLETTER, is greatly enhanced by their supply of many of the publications they review, without charge. The value of such free issues is often the difference between obtaining a publication or not, as payment in a foreign currency is often prohibitively difficulty.

Both authors have had assistance from the International Agricultural Research Centers such as those in Mexico (CIMMYT), Nigeria (IITA) and India (ICRISAT). Such help has included advice, equipment, and research reports. These centers perform a valuable role in taking on research that is more fundamental or speculative than can usually be justified within the very limited resources of a developing country.

The Tropical Weeds Unit at the British Government Weed Research Organization has provided much help to Zambia over the years, in terms of advice and research reports, though it has recently succumbed to the government cut-backs in spending and been closed.

IMPROVING COMMUNICATION

Publications. Attention was drawn earlier to the importance of technical

journal as a means of contact between the developing country scientist and the mainstream of research elsewhere. The difficulty of maintaining foreign currency subscriptions to journals was also explained.

Substantial aid is available to third world countries, but donors have preferences in the way they give, and commitment to a never-ending subscription is not one of them. A way around this problem could be for a donor to make a single grant of, let us say, $200,000 to be set up as an investment trust in the donor's country. A return of 10% could be split, 6% to maintain the capital, and 4%, or $8,000, for subscriptions to 200 journals at an average of $40 each. These funds would, of course, already be in foreign currency.

In developing countries, the publication of the researcher's work is often unlikely. This has kept many valuable research results in the files of their authors, while this information should also reach scientists with similar weed problems in other countries. Could the Latin American Weed Science Society (ALAM), assisted by the International Plant Protection Center, issue a journal with at least the abstracts from relevant work in that continent?

We've seen valuable contributions, like Compton's Annotated Bibliography on Small Farm Weed Control (1) or Robert Zimdahl's review on Weed-Crop Competition (7). Many people would benefit from a translation of this last book into Spanish and French. It would also be good to see similar publications on topics such as:

- weed management in reduced tillage systems, and
- weed management in multiple croppings.

These are just two examples of areas where research is needed in Latin America.

At the University of Chapingo, in Mexico, 300 students take a weed control course every year and do most of their learning from notes taken during the lectures. Translated bibliographical material is still very scarce. Could some of the well-trained Latin American weed scientists be assisted in writing

a textbook with emphasis on relevant Latin American situations? Could ALAM undertake this project? Can this effort be encouraged and supported in other regions as well?

Training. Two areas are considered here, short courses, and the inclusion of weed science in University agricultural syllabuses. Until more universities and agricultural schools become active in weed science, an attempt to cover this gap would be the implementation of short weed management courses.

These courses run from a few days to a few weeks. They are usually in the country of the participants so that training is given under local conditions. They can be structured to meet the needs of the participants and are a very effective way of transferring information and technology. Several such courses have successfully been run in Latin America and the Philippines (2), and others are planned for Africa. These short courses should provide enough opportunities for "hands on" and field experience; they also allow identification of promising individuals for further training or collaboration. It is important to train people with potential to train others in their own environment.

The inclusion of an element of weed science in University agricultural courses has been successful in Mexico. Students have selected weed science as a subject for their research theses, and the programme has been a stimulus in the development of the Mexican Weed Science Society. We do not know of attempts to introduce weed science into agricultural courses in smaller countries.

Local scholarships. Several aid schemes offer scholarships to developing country scientists, usually for first or higher degrees, in developed countries. Such courses are often given under extraordinarily different conditions to those the scientist will later be working in: high capital, low labour, different climate, crops, and weeds and, in some cases, a new language. Applicants are attracted by the prestige of overseas travel and and by the financial advantage of free board and lodging while their salary accumulates at home. But at the end of two or three years, trainees are dropped back into their old environment of limited facilities. Library services, technicians, workshop facilities, access to experienced colleagues, and advanced equipment are all removed and they are left alone to do what they can.

A local scholarship could avoid these problems while simultaneously doing much to improve local facilities. Developing country scientists would be invited to present a case for sponsorship of their home-based research for perhaps a 5-year period. It would include a package of liaison with experienced persons abroad, journal subscriptions, equipment, local transport if needed, and assistance with publication of the results. It should probably include occasional visits from an overseas 'tutor' and attendance at one or two international meetings.

Such a system would attract those primarily interested in research. And it would leave them settled in a reasonably productive environment.

International Agricultural Research Centers. It was earlier said that the work of these centers was seen to be useful and of a nature that could often not be handled by a developing country. This situation could be improved further by the centers inviting developing country scientists to participate in selecting items for research and to take part in some programmes. The plant breeders seem to be ahead of the weed scientists in this matter.

The international centers can contribute to weed science research by having themselves a weed research project with at least one full-time weed scientist. This does not happen at some of the most relevant centers[1/] (3).

CONCLUSION

Despite differences amongst developing countries, there is a common factor of the transfer of weed science technology being restricted by remoteness and communication problems, and by shortages of trained staff and, to some extent, funds. All but the last of these factors have been largely overcome in the developed world, which offers some hope that they may one day be resolved in the developing countries too.

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To improve the status of weed science technology communications in developing countries, attention should be paid also to the transfer of technology within and among these countries.

Foreign advice should make a strong effort to understand local agriculture and to promote in their counterparts an integrated weed management perspective. On-farm research and demonstration activities should be encouraged.

Equipment and literature, including translated material, should be sent to individuals in an effort to concentrate aid on specific projects.

Regional and national weed science societies still need to be promoted and many will require financial help; industry and foreign aid organizations therein have a good opportunity to help. These societies should assign first priority to the publication of research progress reports in their respective countries and to promote the teaching of weed science at universities and agricultural schools.

Workers in developing countries are clearly disadvantaged in comparison with their colleagues in the developed world, although it is probable that their problems are just as challenging and their successful solution equally satisfying. The need, and potential, for improved weed control in these countries is large (4, 6, 7) and the rewards, in terms of better fed and therefore more stable and productive populations, must also be large.

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CONSTRAINTS TO WEED SCIENCE TECHNOLOGY TRANSFER IN DEVELOPING COUNTRIES

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INTRODUCTION

The objective of the symposium is to understand better the process of communicating weed science technologies in developing countries. I take the view that the transfer of weed science technologies is no different from the transfer of other agricultural technologies. I shall, therefore, discuss agricultural technology transfer in general and identify factors that influence the transfer process from those who develop the technology to those who utilize the technology. I will, however, also call attention to unique features known to affect the transfer of weed science technologies, particularly the transfer of weed control technology. In both cases (i.e., transfer of agricultural technology in general and weed science technology in particular), I will draw upon the knowledge and experience gained in efforts to transfer technologies so that these may be utilized to increase rice production in developing countries, particularly of Asia.

TRANSFER OF AGRICULTURAL TECHNOLOGIES

When addressing the issue of technology transfer (synonymously, overcoming the technology gap), it is important to recognize that a chain of events takes place from undertaking research, generating technology, and transferring technology into an effective use pattern. Obviously, the chain is only as strong

as its weakest link. The whole process involves not only the product (the technology), but also the individuals who implement the transfer and those who make policy decisions that influence the effectiveness of implementation. It is not too difficult to understand that in such a situation--where a chain of events involves several institutions and individuals--there is a natural tendency to "put the blame" on others when things do not turn out as expected. In the beginning, the failure of farmers to adopt the new rice technology was commonly thought, particularly by researchers, to be due to:

- farmer's conservatism and backwardness; and,
- failure of extension to do its job of technology dissemination.

In addition, it is commonly pointed out that biological scientists initially involved in the development of the technology paid little or no attention to the economic implications of the application of the technology.

I will call attention to three of the more important factors that could be, and have been, shown to be constraints to the transfer of technology and/or to its utilization by rice farmers.

Is the technology useful to the farmer in his environment? Farmers in developing countries, and especially the small farmer with limited land and capital resources, often regard new technology with skepticism. Usually it is not unwillingness to try the new technology--rather, that the new technology has often failed him.

To illustrate my point, I will draw upon the study made by R. Barker and T.K. Pal (1) on "Barriers to increased rice production in Eastern India." The three states of eastern India--Bihar, West Bengal, and Orissa--account for 40% of India's rice area and 34% of its total rice production. A comparison of these eastern states with rice-producing states in northern India is shown in Table 1. Rice yields in the southern area are about double those in the eastern states, so that while 40% of the total rice area is accounted for by the three eastern states and the southern states only 20%, each contributes about the same to India's total rice production. A higher level of adoption by the southern states of modern semidwarf varieties, use of fertilizers and irrigation, all of

Table 1. Statistics for selected states of India, 1974.

	Northern India	Southern India	Eastern India
Total rice area (%)	2	40	40
Total rice production (%)	3	33	34
Rice irrigated (1970) (%)	89	84	29
Area in modern varieties (%)	71	62	12
Fertilizer (kg NPK/ha)	28	28	10
Yield paddy (t/ha)	3.0	2.6	1.4
Area in rice (000 ha)	9,000	7,900	15,100
Total Production (000 t)	2,700	20,540	21,140

States selected:

Northern India: Punjab, Haryana, Jammu, and Kashmir.
Southern India: Andhra Pradesh, Karnataka, Kerala, and Tamil Nadu.
Eastern India: Bihar, West Bengal, and Orissa

Source: Barker, R. and T.K. Pal. 1979. Barriers to increased rice production in Eastern India. IRRI Res. Paper Ser. Int'l. Rice Res. Inst.

which are highly complementary, were responsible for the higher yield. The information in Table 1 suggests why yields are lower in the eastern states, but it does not tell us why the farmers are not using "modern technology." For indeed, there are many scientists who believe that technology does exist in the experiment stations of eastern India which, if applied on farmers' fields, would significantly increase farm yields. Let me try to show why for good reasons farmers in eastern India do not use the modern semidwarf varieties.

In terms of water regime, the 15.1 M ha rice area in eastern India may be classified as:

- irrigated rice--water from canals, pumps, storage tanks, etc., utilized for irrigation;
- upland unbunded rice--water not impounded;
- deepwater rice--water depth exceeds 100 cm from tillering to flowering.

Furthermore, rice areas where water is impounded but totally dependent on rainfall for irrigation may be considered in three groups based on water depth:

- shallow rainfed--up to 20 cm water depth;
- intermediate rainfed--21-50 cm water depth;
- semideep rainfed--51-100 cm water depth.

The water depth determines the plant type that could be grown. The modern semidwarf varieties do well in water depths up to 20 cm. A few modern varieties of medium height could be planted in areas with water depths of up to 50 cm. On the other hand, the traditional tall varieties survive in water 1 m deep and the floating rices are grown in areas with water depths greater than a meter. One other characteristic of the variety needed for this area is that of photo-period sensitivity. This characteristic allows harvest time to coincide with the recession of the deep waters. Most of the modern varieties--nonsensitive to photoperiod--become unsuitable with increase in water depth.

The example above illustrates a biological constraint associated with the technology:the technology is not suitable to the farmers' particular growing environment.

Is the use of the technology economically feasible? Economic feasibility of the application of a technology could be determined by a calculation of the benefit:cost ratio resulting from the use of the technology. More and more economists work alongside biologists in the effort to develop technology for farmers so that there is ample opportunity to estimate the economic implications of a technology before its widespread introduction to farmers.

I will call attention to other kinds of economic implications that could become constraints to the adoption of a technology no matter how biologically useful it may be. I illustrate this through two examples of recommended rice production technologies.

The first example is the recommendation to make a basal application of fertilizer at the time of the last harrowing. In a survey of Laguna farmers

(3), it was found that 90% of the 50 farmers interviewed were aware of the recommendation. In fact, although many of the farmers have tried the recommendation, only a few still practice it. One of the main reasons given by the farmers for abandoning the practice of basal application was that this fertilizer management practice leads to earlier weed growth and to higher weed costs. Many farmers also mention increase in insect and disease problems.

The second example is the recommendation to plow soon after rice harvest, particularly in areas where only one crop of rice is grown a year. Insect life cycles (e.g., yellow stemborer, green leafhopper) are interrupted by immediate plowing under of the stubbles. Also, the practice often reduces water loss. At least in Central Luzon (the rice bowl of the Philippines) farmers point out that the ratoon crop, no matter how low the yield, which is lost by the practice is a critical fall-back resource for farmers after natural disasters and at all times for the landless workers (3).

Is there a political will and an effective organizational set-up? I will draw upon the experience in the diffusion of modern rice technology among farmers in Burma. High-yielding modern rices were first introduced in Burma in 1966, but their adoption by farmers was slow. One of the reasons was, "the agricultural extension organization was small and could not agressively promote the new modern varieties" (5). Admittedly, there were other reasons for non-adoption associated with the technology (biological constraint). Thus the government decided that since "it was clear from the scope of the problem and the size of the potential area of production... the approach would have to be one of selective application and exploitation." With the objective to increase milled rice production by 0.1 M tons annually, the government, through the Agricultural Corporation of Burma, designed/developed the "Whole Township Rice Production Program." The program had five components:

- proven new technology;
- government support and leadership;
- selectivity and concentration;
- community organization;
- demonstration and competition.

I will comment on two components--government support and leadership and community organization--to show the kind of political will and organization utilized. I quote from the paper, 'The impact of a special high-yielding rice program in Burma:' "The Burma Socialist Party, state agencies and the Peasants Asiayone provided political leadership in and support of the Whole Township Rice Production Program at the national level. Their lower echelon levels provided leadership down to the village level.

"Four important committees were formed at the township level:

- Agricultural Management Committee;
- Cultivation Activities Committee;
- Procurement and Distribution of Inputs Committee;
- Disease and Insect Control Committee.

"The Township Party Unit Committee and the Township People's Council closely supervised the program. As residents of the townships, the members were familiar with the physical, biological, social, and economic conditions of their constituents. They also had the authority to coordinate the activities of the various government agencies within the township and could make decisions during the implementation of the program.

"Organizationally, there is one divisional manager for each township, a village tract manager for each village tract, and a village manager for each village. The extension workers who are in constant touch with the farmers are the village managers and the village tract managers."

In order to make full use of the new technology, some sort of community organization was essential. For instance, the recommended plant population was 320,000 hills/ha, double that normally used by farmers, thus requiring more transplanters. Community organizations provided additional transplanters by reviving the age-old Burmese practice of helping each other through voluntary labor. The higher labor requirements were also met by increasing the remuneration of the village workers and recruiting transplanters from the urban areas.

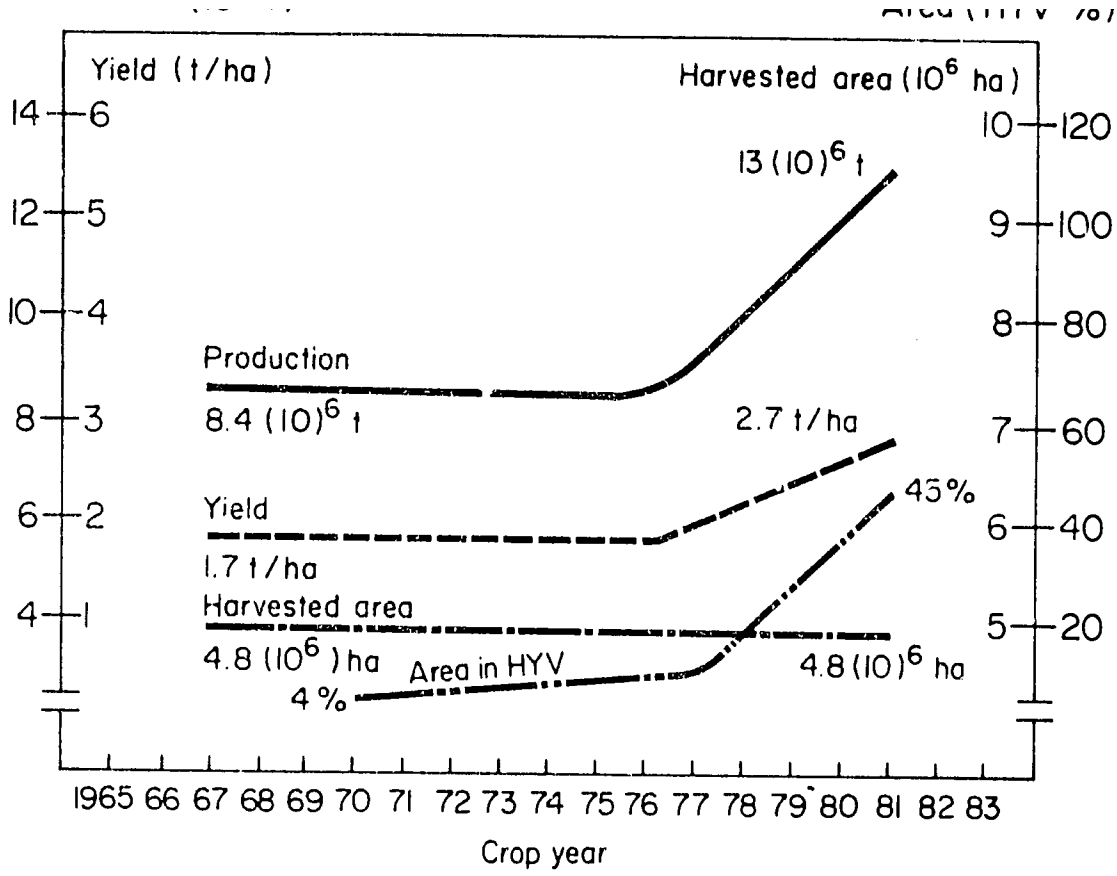

Fig. 1 Rice production, yield, area harvested and area in HYV of Burma from 1967-81; indicating increased production, yield and area in HYV as outcome of whole Township Rice Production Program started in 1977.
(Source: Khin Win, Nyi Nyi and E.C. Price, 1981.)

Just briefly on the outcome of the transfer of technology program, the average yields of the townships before and after the program all showed increases and all the participating townships realized favorable economic returns from the program.

The long-term trend in area planted to rice and rice production in Burma is shown in Figure 1.

The above are some of the more important issues that have been shown to determine whether or not the technology is effectively transferred to the farmer for whom they were supposed to have been designed and developed.

Next I would like to focus my presentation a little more specifically to the transfer of weed science technology and more specifically draw upon the experience from the transfer of weed control technology for rice production.

TRANSFER/ADOPTION OF WEED CONTROL TECHNOLOGY FOR RICE

Rather than talk about the constraints, I will discuss factors that have been shown to influence adoption of weed control technology by farmers and/or the level/kind of weed control technology adopted by farmers.

Weed control technology is part of a package. In crop production, a technological input does not by itself result in increased yields; it is well-recognized that it is more often a "package of technology" that accomplishes the objective.

Rice farmers seem to adjust the intensity of their weed control to the potential productivity of the crop under their particular conditions. Weed control, for instance, is much more intensive where yields are high, but intensive weed control by itself will not have much impact on yields where water control, variety, and other production factors are limiting.

Farmers' access to credit. At least in irrigated, transplanted rice areas, farmers' access to credit may not be a major constraint to achieving adequate levels of weed control. A specified level of weed control can be achieved by different combinations of labor and other nonlabor inputs. Within limits, labor can substitute for other inputs in controlling weeds. Weed control practices which complement other components of the new rice technology are significantly different from practices involving application of fertilizers or insecticides. Human labor is no real substitute for nitrogen; on the other hand, pulling a weed out or killing it with herbicide can achieve the same effect. However, because of the need for a package of technology, access to cash or to credit could have another influence on the adoption of weed control technology. The absence of such an access lowers the farmer's ability to use other inputs, such as fertilizers, to increase yields. Consequently, the potential gain from better weed control is reduced and, therefore, makes the adoption of a better weed control technology less attractive.

Economics of weed control. Rice farmers are aware of the impact weeds have in reducing yields and use a combination of methods to obtain the level of control they desire. Farmers' "rationality" in adopting or not adopting new technology is now widely accepted. Farmers will adopt the new weed control technology only if it is more profitable than the one they are using. For instance, where the use of herbicides is being introduced in an area where farmers have traditionally used handweeding/other methods of mechanical control, obviously the adoption of the new technology will depend on the cost of hired labor, the cost of the herbicide, and the returns from the increase in yield due to the control of weeds. For instance, among Laguna (Philippines) farmers, labor utilization for weeding increased between 1970 and 1975 when herbicide prices increased sharply and wages declined. On the other hand, between 1975 and 1978 labor for weeding per hectare decreased when wage rates increased and herbicide prices remained unchanged (Fig. 2) (2).

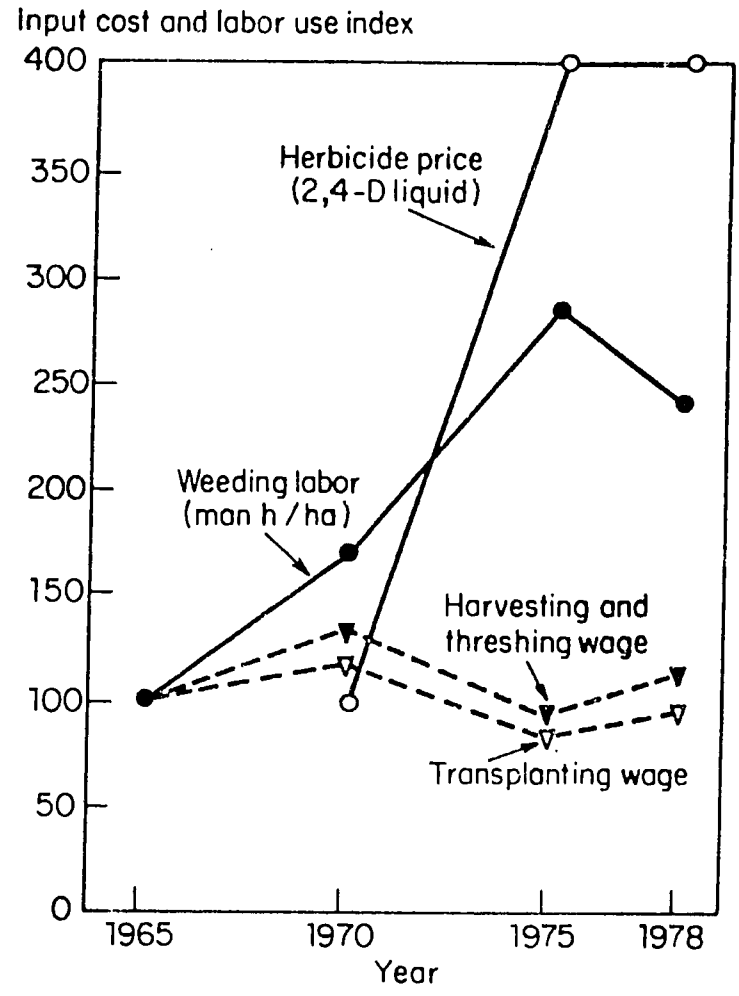

Figure 2. Effect of relative input costs on weeding labor for 45 Laguna farmers, 1965-1978 (from Smith and Gascon, 1979).

There is great diversity in prices the Asian rice farmers have to contend with. During the study years, rice prices ranged from US $0.06/kg to $0.19/kg while labor cost ranged from $0.50/day to $2.38/day. Thus, in areas with low labor cost, little or no herbicide expenditure was reported, while those areas with high labor costs reported the use of herbicide equal in value to 25-40 kg of rough rice per hectare.

Farming system. The overall farming system into which the new weed control technology is to be introduced must be taken into consideration. A weed control technology which may be profitable when the rice crop is considered in isolation may not be profitable when the whole farming system is considered. For instance, a farmer who practices rice-fish culture will not adopt weed control technology that includes chemicals toxic to fish. A rice farmer also engaged in livestock raising may not want to remove weeds until they have reached a certain stage of growth. A tenant-landlord arrangement could be a further disincentive because while all the "weeds" are harvested and utilized by the tenant farmers, they stand to gain very little from increased rice yield resulting from early weeding.

The transfer of weed science technology is influenced by the same kinds of factors that affect the rate/the enthusiasm agricultural technologies in general are adopted by farmers. The technology must be suitable to the farmer's particular growing and socioeconomic environment. The technology must not only be biologically adapted to the farmer's growing conditions; maybe more importantly, its adoption must be economically beneficial to the farmer. While biological adaptation can be evaluated and the financial advantage of the use of the technology can be calculated, it is not always easy to understand and/or appreciate the more subtle socioeconomic implications of the farmer's adoption (or rejection) of the technology. After a technology has been proven to be biologically useful and socioeconomically advantageous to the farmer, still there must be the political will and an effective organizational set-up in place if the technology is to be utilized by farmers to such an extent as to bring about the increased production expected from its adoption.

More specifically, in terms of the transfer of weed control technology, it seems that farmers adjust the level of weed control they practice to the potential productivity of their crops. The implication is that factors that affect the adoption of other production technologies will, therefore, influence the level/kind of weed control technology adopted by farmers.

Finally, it should be recognized that weed control technology does not by itself bring about increased yields; it is a fact that a package of technology including weed control technology is needed to attain better yields and increased production.

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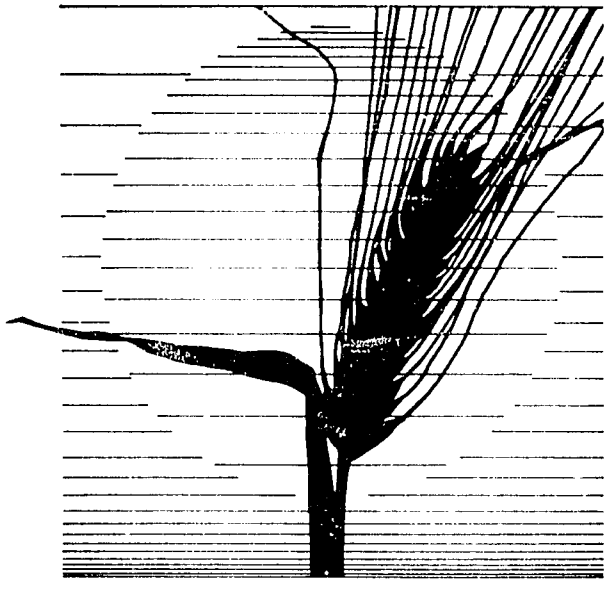

SOCIOECONOMIC CONSTRAINTS AND THE ADOPTION OF WEED SCIENCE TECHNOLOGY IN DEVELOPING COUNTRIES

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INTRODUCTION

"Weed management is perhaps the most important single element needed to improve crop stability in the humid tropics..." (5). Although this statement by Harwood focuses on "stability" and the humid tropics, I take it for granted that good weed management is also critical to the success of efforts to increase crop yields and is important throughout the developing world. In this paper, I examine some of the socioeconomic characteristics of developing countries that are relevant to choosing the type of weed management techniques that are likely to be most appropriate. I will argue that it is important to identify a logical sequence of "low cash-flow technologies" adapted to the needs of small farmers with very limited purchasing power.[1/] This is not because "small is beautiful," but because of the nature of the socioeconomic constraints that limit the options that are feasible in developing countries. Those constraints are especially severe in the lower income, late-developing countries where agriculture still provides employment and income for some 50% to 80% of the labor force.

1/ I will argue that this emphasis by Harwood (4), on "low-cash flow technologies" is relevant to the sectorwide choice of agricultural technologies and not merely a concession to the fact that small farmers face special problems.

Countries such as India, Bangladesh, Kenya, or Tanzania confront special opportunities and problems because of the large stock of scientific knowledge and technologies that is at their disposal. This is because technology transfer is a double-edged sword. The enormous technological backlog that is available reduces the time and resources required to produce useful knowledge, thereby offering the possibility of a very rapid economic growth. But those opportunities for technology borrowing are a mixed blessing because of the strong possibility that the technologies that are transferred will be ill-suited to the resource endowment of a low-income country. The fundamental problem is that efforts to modernize agriculture in these countries are limited by an acute shortage of capital in all its forms--human skills, knowledge, and organizational capital as well as physical capital. Hence, the importance of the timing and sequence in which innovations are introduced and of choosing and adapting technologies to take account of the socioeconomic characteristics of the low-income developing countries.

The fundamental difference in the technologies appropriate for a developing country as contrasted with developed countries has been well illustrated by a comparison between Kenya and the U.K. (9). It was noted that in Kenya the total labor force was growing at an annual rate of 3.3% compared with 0.4% in the U.K.[2/] Per million population, Kenya must find eight times as many additional productive jobs each year as the U.K. However, Kenya has available only one-fifteenth of the resources per million population for creating new jobs. If Kenya tried to provide the additional jobs in such a way that the new employment opportunities created would be of the same kind as in the U.K., less than 1% of the annual additions to the labor force would find jobs.

The combination of a rapidly growing labor force, and agriculture's large share in the total labor force, means that in late-developing countries a large

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2/ These estimates were for 1973; more recent estimates indicate that Kenya's rate of natural increase is approximately 3.9% so that the country's population of working age will be increasing at more than 3.3%.

percentage of the annual additions to the work force must find employment in agriculture. For example, if agriculture accounts for 70% of a country's labor force and nonfarm employment is increasing at the relatively rapid rate of 4% per year, just over 50 years would be required to reach the turning point when the absolute size of the farm labor force begins to decline, given a 2.5% annual rate of increase in the total labor force. However, if the total labor force were to increase at a constant rate of 3%, 95 years would be required to reach that turning point.[3/] These structural-demographic characteristics have especially significant implications for the choice of technologies for agricultural development in a country such as Kenya where some 80% of the labor force was still dependent on agriculture in 1978 as compared to approximately 2% in the U.K. and the U.S. (12).

It is unrealistic to assume that Kenya's population will continue to grow at its present high rate, but it seems clear that the decline in the country's population growth rate will be a slow process; and there will, of course, be a further time lag before a decline in the birthrate will be reflected in a decline in the rate of increase in the population of working age. It has been projected, on the basis of a likely estimate of changes in the rate of natural increase and fairly optimistic assumptions concerning the growth of nonfarm employment, that Kenya will experience a fourfold increase in its rural labor force between 1969 and 2024 in spite of a sixteenfold increase in the economically active population in urban areas (10).

In less developed countries, past growth of population has already reduced the scope for expanding the cultivated area. Continuing growth of their farm population, therefore, means subdivision of holdings and a decline in the size of the average farm unit.

3/ These results are calculated from the following identity which shows how the rate of change in a country's agricultural labor force (L') will be determined by agriculture's initial share in the labor force (L_a/L_t) and the rates of change in the total labor force (L'_t) and in the nonagricultural labor force (L'_n):

$$L'_a = (L'_t - L'_n) \frac{1}{L_a/L_t} + L'_n$$

A retrospective analysis by Vyas (11) examines this process in India. It is especially striking that between the early 1950s and early 1970s the number of "marginal" farm households with less than 0.4 hectare more than doubled, rising from 15 to 36 million in less than 20 years. These marginal and landless households bore the brunt of the increasing pressure of population on the land. But it was not a case of "the small getting smaller because the big were getting bigger." The number of "big" and "large" farms declined, and there was a decline in the average size of holding in every size category. Clearly, the driving force was the increase from 49 million to 81 million in the number of farm households, coupled with a trivial increase in the cultivated area from 123.5 to 126.0 hectares. Hence, the average farm holding declined from 2.6 to 1.5 hectares. Moreover, it is clear that this trend is continuing and will continue for many years.

Even in countries where there is still substantial scope for expanding the land area, it is highly important to emphasize a sequence of "low cash-flow technologies." This is because of the cash income or purchasing power constraint that is inevitable when the number of farms is very large relative to the number of households dependent on purchased food. This constraint is related most directly to the small domestic commercial market for agricultural products. Under favorable circumstances, rapid expansion of production for export can enable a country's agricultural sector to enlarge its cash income at a rate which substantially exceeds the growth of domestic commercial demand. In general, however, the possibility of producing export crops qualifies but does not eliminate the significance of this cash income constraint.

ALTERNATIVE PATTERNS OF AGRICULTURAL DEVELOPMENT

Some farms in a developing country can escape from this cash income or purchasing power constraint that is a general feature of the agricultural sector. In many developing countries, agriculture is characterized by a dual-size structure: a relatively small number of large, highly commercialized farms coexist with a much larger number of small and predominately subsistence farms. Agricultural scientists familiar with the array of technologies now available for rapidly increasing farm productivity may see this as a logical means of enabling at least some farms to take advantage of modern scientific

knowledge, including the recent advances in weed science. Furthermore, it might be argued that concern about the adverse effects of a dualistic pattern of agricultural development on opportunities for productive employment in agriculture and on income distribution are misguided. In low-income countries with an urgent need to expand food production, it might be asked, shouldn't the growth objective take priority over equity considerations?

If indeed a substantial trade-off between growth and equity is inevitable, it would be difficult to challenge the view that priority should be given to growth. It is clear, however, that some countries--most notably Japan, Taiwan, and South Korea--have been able to pursue "dispersal strategies," i.e., policies and programs which emphasize divisible "low-cash flow" technologies that make it possible to progressively modernize a large and increasing percentage of the existing small-scale farms. Moreover, there is persuasive evidence that the broadly based, employment-oriented pattern of agricultural development resulting from their dispersal strategies has had significant economic as well as social advantages compared to a dualistic pattern of development resulting from "focus strategies" in which scarce resources are concentrated within a subsector of large-scale farms or within limited areas singled out for preferential treatment (7, 6, 2).

I stress this choice between alternative strategies leading to different patterns of agricultural development because an emphasis on focus strategies tends to preclude the possibility of successfully implementing dispersal strategies. That is, to a considerable extent, the two strategies represent mutually exclusive alternatives. To my knowledge, Malaysia is the only developing country that has been able to simultaneously and successfully pursue focus and dispersal strategies. This was possible because of a number of virtually unique factors, notably the availability of abundant agricultural land and a heavy concentration on production of rubber and other export crops by both the large-scale plantation and the small-scale sectors. Even in Malaysia broad progress in the smallholder sector has been handicapped to some extent by the orientation of research toward technologies best suited to plantation production. Nevertheless, there have been a variety of dispersal strategies--for rubber and oil palm as well as rice and other food crops--that have fostered widespread increases in productivity and income among small holders. In contrast, rubber improvement

programs in the outer islands of Indonesia have emphasized a focus strategy that is so resource intensive that it will be a half century or more before the great majority of small-scale rubber producers can benefit from improvement programs unless there is a shift in policy toward a dispersal strategy (1).

Before I comment on the choice of weed management technologies appropriate to late-developing countries, I want to present a schematic view of the principal factors influencing changes in farm productivity (Figure 1). Attention is focused on output per worker in the agricultural sector as the key factor influencing increases in per capita farm incomes as well as the increases in output required to meet the needs of an expanding nonfarm sector. A distinctive feature of increasing agricultural productivity is the importance of the interaction between farm-level factors and socially determined factors. Apart from specific innovations, farm productivity will be influenced strongly by the extent to which the technical and managerial efficiency of farmers achieves cost-minimization. The most important socially determined factor operating at

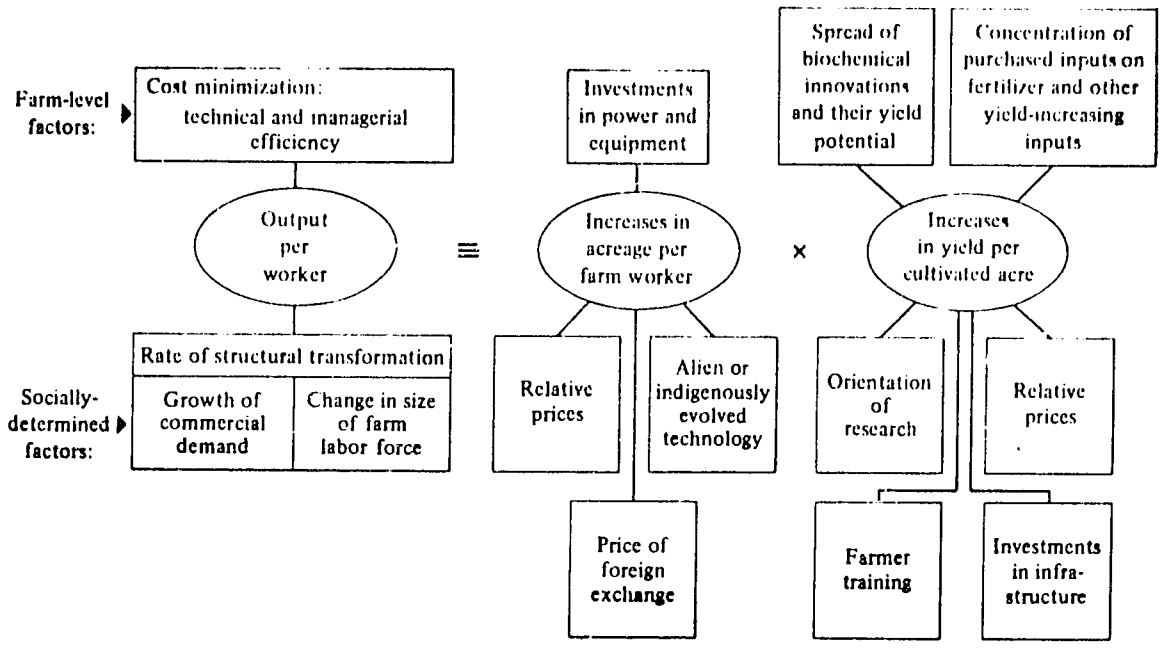

Figure 1. Schematic Summary of the Principal Factors Influencing Changes in Farm Productivity. (Source: Johnston and Kilby [8]).

this general level is the rate of structural transformation, especially the increase in the nonfarm labor force relative to the size of the farm labor force. This structural transformation process is the major determinant of the growth of domestic commercial demand and of the direction as well as the rate of change in the size of the farm labor force. Historically, the truly rapid increases in farm labor productivity have occurred when a decline in the size of the farm work force provided large scope for labor-saving innovations affecting the entire agricultural sector rather than just a subsector of atypically large and commercialized units.

The more specific policies, investments, and innovations shown on the right-hand side of the diagram are partitioned into two sets of factors--those that increase acreage cultivated per worker (A/L) and those that increase yield per acre (Y/A). Many of us have used this partitioning between factors that influence A/L and those that influence Y/A because the former tend to correspond to mechanical innovations and the latter to biological-chemical innovations. At any point in time this partitioning of the increase in farm labor productivity (Y/L) into A/L and Y/A is merely an identity. But the partitioning is useful because, to a close approximation, the increase over time in Y/L will be equal to the sum of the rate of increase in A/L plus the rate of increase in Y/A.

Not surprisingly, with the dispersal strategies pursued in Japan, Taiwan, and South Korea, the historical increases in Y/L have been mainly the result of increases in Y/A. In fact, an impressive 3.3% annual increase in Y/L in Taiwan between 1952 and 1966 was achieved in spite of an annual decline of 0.8% in the A/L component resulting from a substantial increase in the farm work force leading to a reduction in the average farm size during that period. (It was not until the late 1960s that Taiwan reached a "structural transformation turning point" and the absolute size of the farm labor force began to decline.) The special significance of yield-increasing innovations such as improved seed-fertilizer combinations is that they are divisible and complementary to the farm-supplied inputs of labor and land. Hence, the can facilitate the sector-wide progressive modernization of a country's small-scale farm units based on a gradual expansion in the use of off-farm purchased inputs. Moreover, requirements for the particularly scarce resources of capital and foreign

exchange are minimized because these technologies permit fuller as well as more efficient utilization of the relatively abundant resource of farm labor.

It will be obvious that weed management techniques do not fall neatly into either of the two categories. A shift from intensive hand weeding to the use of herbicides, for example, is mainly acreage-increasing and labor displacing. But the adoption of weed management techniques that result in better weed control is, of course, yield-increasing and may lead to an increase in labor inputs per hectare. For example, in the Philippines the spread of the very simple hand-pushed rotary weeder, that had been developed much earlier in Japan, had the effect of increasing labor inputs for weeding. Although the rotary weeder reduced the labor for a given "amount" of weeding, the total application of labor for weeding was increased. It seems clear that the explanation lies in the increased marginal productivity of labor applied to weed control because of the combined effects of using the rotary weeder and of adopting the high-yield, fertilizer-responsive varieties of rice that began to spread in the late 1960s.

CONCLUDING COMMENTS

The general conclusion suggested by this analysis of socioeconomic constraints has been expressed succinctly by Young et al. (13): "In labor-abundant regions with few alternative employment opportunities like Northeast Brazil, agricultural scientists should stress development of a labor-using, yield-increasing technology. Examples include locally adaptive high-yielding seed varieties, better soil and water conservation practices, low-cost irrigation techniques, and improved manual and animal-powered weed control implements and methods."

I suspect that if I were a weed scientist, I would not like that conclusion. Certainly the temptation would be strong to focus on those "islands" of modern, large-scale, highly commercialized farming where cash income is sufficient for the use of herbicides along with a wide range of other purchased inputs. Given the technical efficiency of some of the herbicide-based techniques now available, government subsidies to increase the private profitability of herbicide use might even seem desirable from the point of view of a weed scientist.

I assume, however, that weed scientists are first of all agricultural scientists and, like agricultural economists, are concerned with the multiple objectives that must be realized if agricultural and rural development are to lead to significant improvement in the well-being of the rural population. The nature of the problems confronting the contemporary low-income countries suggests that even a short list of essential objectives would include: 1.) accelerating the expansion of farm output; 2.) generating productive employment opportunities (both within and outside agriculture) for a growing labor force; 3.) reducing the particularly serious manifestations of poverty (especially malnutrition and excessive mortality and morbidity among infants and small children), and 4.) creating an environment favorable for slowing the rate of growth of population.

This emphasis on multiple objectives is not motivated by a penchant for grandiose ideas. In fact, I am convinced that one of the major sources of ineffectiveness in the design and implementation of rural development strategies is the tendency to overcommit resources by undertaking a great range of activities, each of which seem desirable when considered in isolation, but which add up to requirements for money and trained manpower that exceed the resources available. A major conclusion of my recent book with William Clark (7) is that widespread and sustained progress toward improving rural well-being in low-income countries requires that only a few of the highest priority, most mutually reinforcing programs should be undertaken.

Historical experience and theoretical considerations, however, seem to support the conclusion that broad-based, employment-oriented agricultural strategies can and should make a notable contribution to the multiple objectives of rural development. The major challenge confronting agricultural scientists and economists concerned with fostering progress in developing countries is to identify sequences of innovations adapted to the needs of small farmers subject to a severe purchasing power constraint and operating under a variety of agroclimatic conditions. In general, I believe that Binswanger and Shetty (3) are right in concluding that farmers should not be expected to buy herbicides when their "resources are so severely constrained that they cannot even invest in better seeds or fertilizers." To be sure, there may well be situations where herbicide use merits a high priority in spite of existing

socioeconomic constraints. Introduction of minimum tillage techniques in situations where this is essential to reduce soil erosion and to increase moisture retention might be an example. But given the sectorwide constraints that need to be considered, there is a strong presumption that priority should be given to labor-using, capital-saving innovations.

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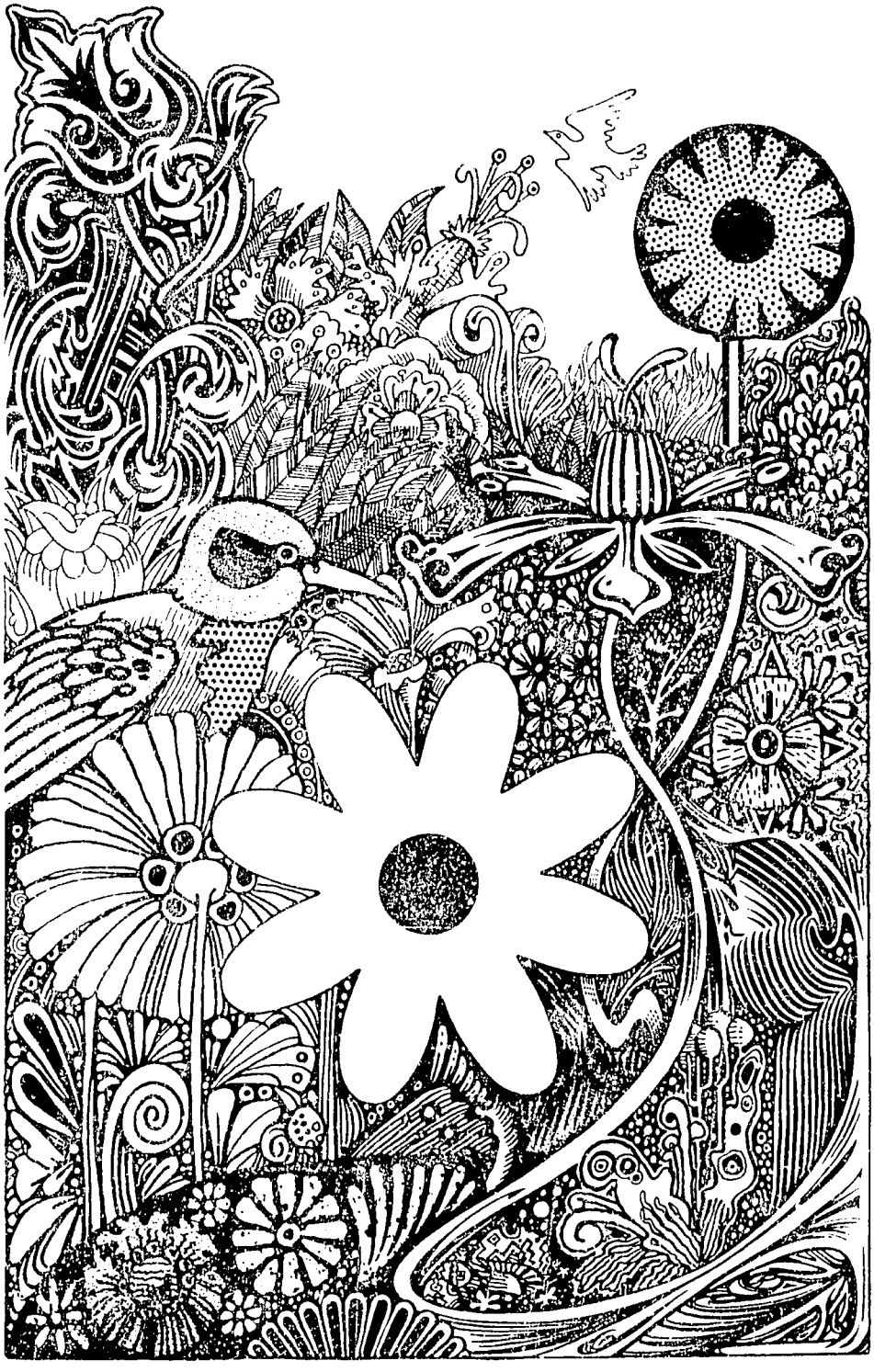

SUCCESSFUL SOIL MANAGEMENT TECHNOLOGIES AND THEIR TRANSFER TO SMALL FARMS IN THE PERUVIAN AMAZON

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INTRODUCTION

The main agricultural system utilized by local farmers in the Peruvian Amazon is the slash-and burn method. It consists of clearing the forest and cropping the land until native fertility provided by the ash is depleted. The large land areas which must be cleared under shifting cultivation, population pressures, and the increasing ecological concerns may soon restrict such practices. Therefore, a sound soil management strategy for continuous cultivation should be developed and made available to the shifting cultivators and accepted by them. Such a development would help to increase food production for the people of the humid tropics and at the same time help to preserve the ecological integrity of much of the yet undisturbed rainforest of the Amazon Basin.

In 1971, North Carolina State University's Tropical Soils Research Program, in cooperation with antecedent agencies of the Instituto Nacional de Investigacion y Promocion Agraria (INIPA), initiated a research project in Urimaguas, Peru, to determine whether continuous food crop production is

possible in an area considered representative of the different climatic, soil, and socioeconomic constraints of the Amazon Basin.

In 1978 it was felt that the improved continuous cropping systems had been developed sufficiently to begin extrapolating them from the research station to small farmers of the area.

The purpose of this paper is to describe some soil management technologies developed during the last ten years and their technology validation in farmer fields near Yurimaguas.

FERTILIZER MANAGEMENT FOR CONTINUOUS CROP PRODUCTION

The field experiments were conducted on nearly level positions of the Yurimaguas Experiment Station in the Low Selva of Peru (5°45'S, 76°5'W, 182 m above sea level). Mean annual temperature is 25°C, while mean annual precipitation is 2200 mm with no pronounced dry season but occasional dry spells. The soil is classified as the Yurimaguas series, a fine loamy, siliceous isohyperthermic Typic Paleudult (Tyler, 1975). Selected soil properties on which field research was conducted are shown in Table 1.

Table 1. Properties of the Yurimaguas Ultisol Used in the Continuous Cropping Experiment Prior to Clearing.

depth	clay	sand	pH	org. C	exchangeable Ca	Mg	K	Al	eff. CEC	Al sat.
(cm)	-----(%)-----			(%)	----------(meg/100 cc)----------					(%)
0-5	6.4	80.2	3.8	1.25	0.84	0.37	0.20	2.05	3.49	59
5-13	10.1	69.6	3.7	0.84	0.05	0.03	0.04	2.63	2.76	95
13-43	14.9	61.0	3.9	0.42	0.06	0.03	0.03	3.11	3.24	96
43-77	16.6	57.2	4.0	0.29	0.03	0.01	0.02	3.12	3.20	98
77-140	24.8	50.6	4.1	0.18	0.03	0.01	0.03	4.48	4.58	98
140-200	24.1	53.7	4.4	0.17	0.06	0.03	0.04	3.80	3.94	96

Source: Tyler (1975)

High-input Soil Management Technology

The high-input soil management technology consists of eliminating soil fertility constraints by applying the necessary amounts of fertilizers and lime for cultivars with high yielding potential.

Methodology. In the continuous-cropping experiment using high-input technology, the fertilizer value of the ash from the traditional burn as practiced by shifting cultivators was determined and soil nutrient dynamics and crop yields with and without lime and fertilizer over time of cropping were monitored. Various rotations of three crops per year were employed; in this paper we will summarize results from the upland rice-corn-soybean rotation.

Yields. Figure 1 shows the grain yields of 21 consecutive crops harvested from the same field since it was cleared by slash-and-burn in October 1972,

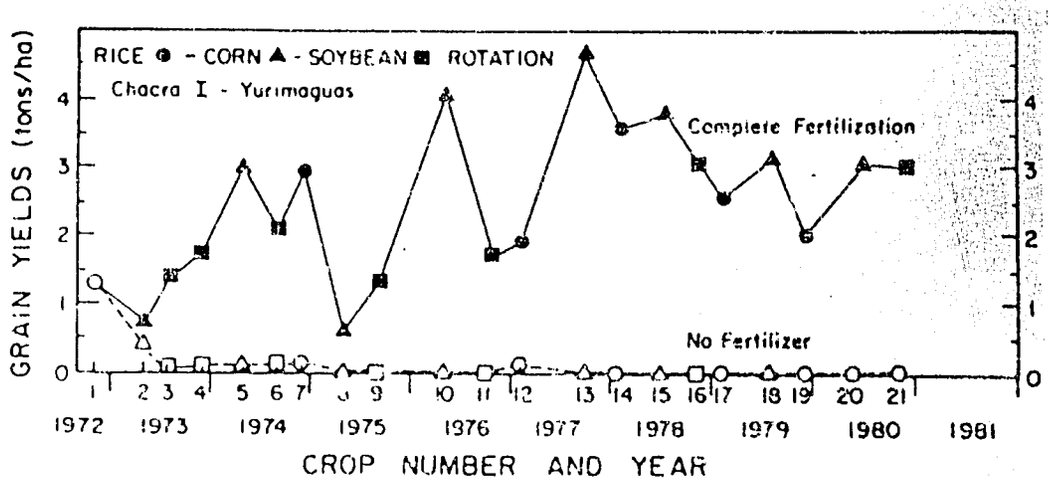


Fig. 1. Yield record of a continuously cultivated plot in an Ultisol of Yurimaguas, Peru with and without fertilization.

Source: Nicholaides et al., (1982)

and cropped with the rice, corn, and soybean rotation. Without fertilization, yields dropped to zero after the third consecutive crop. With complete fertilization, on the other hand, the long-term average yield of this rotation is 7.8 t/ha/yr.

Effects on soil properties. The soil dynamics data from the field experiments and the on-farm extrapolation trials were monitored through periodic soil analysis.

Nutrient management is the key factor for maintaining the production capacity of soils. The timing of the appearance of soil fertility limitations is described as follows: ash from the burning produced a temporary increase in pH, available nitrogen, phosphorus, potassium, calcium, magnesium, and some micronutrients. It also decreased exchangeable aluminum to nontoxic levels. As a result of the fertilizer value of the ash (Table 2), upland rice, the first crop planted, did not suffer from soil fertility limitations. About 8 months after clearing, however, the levels of available nitrogen and potassium were reduced to deficiency levels; additionally sporadic sulfur, copper, and boron deficiencies appeared.

Table 2. Nutrient Contribution of Ash and Partially Burned Material to an Ultisol of Yurimaguas, Peru After Burning a 170-year-old forest.

element	composition	total additions
		kg/ha
Nitrogen	1.72%	67
Phosphorus	0.14%	6
Potassium	0.97%	38
Calcium	1.92%	75
Magnesium	0.41%	16
Iron	0.19%	7.6
Manganese	0.19%	7.3
Zinc	132 ppm	0.3
Copper	79 ppm	0.3

Source: Seubert *et al.* (1977)

Phosphorus and magnesium became deficient during the second year, calcium after the first 30 months, and zinc during the forth year. Manganese deficiency is suspected after the eighth year. Molybdenum deficiencies were detected at times in soybeans.

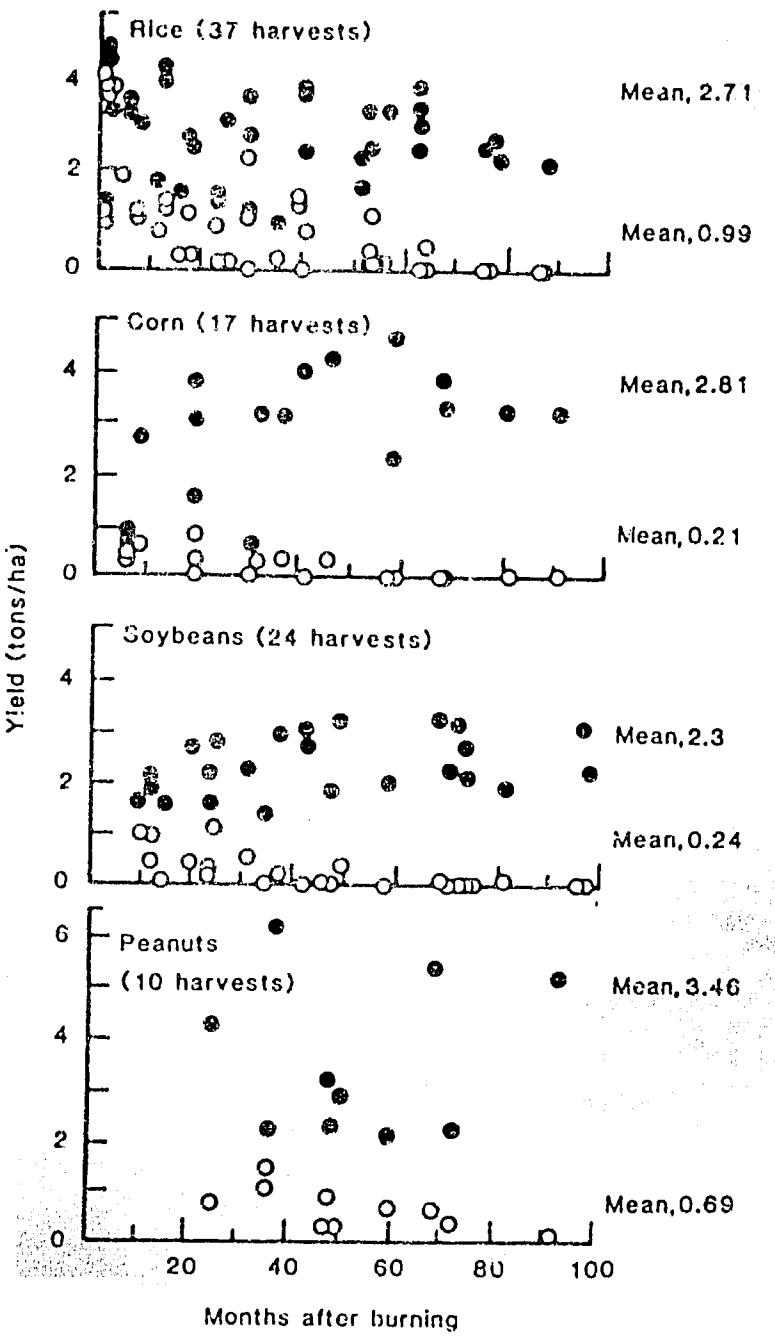


Fig. 2. Crop yields as a function of time after clearing with and without fertilization. Yurimaguas (1972-1980). Source: Sanchez et al., (1982)

Table 3. Changes in Topsoil (0-15 cm) Properties After 7-3/4 years of Continuous Cultivation of 20 crops of Upland Rice, Corn, and Soybeans with Complete Fertilization in Yurimaguas, Peru.

time	pH	org. matter	exchangeable Al	Ca	Mg	K	eff. CEC	Al satn.	available P	Zn	Cu	Mn	Fe
		(%)	(meq/100 cc)					(%)	(ppm)				
Before clearing	4.0	2.13	2.27	0.26	0.15	0.10	2.78	82	5	1.5*	0.9*	5.3*	650*
94 months after clearing	5.7	1.55	0.06	4.98	0.35	0.11	5.51	1	39	3.5	5.2	1.5	389

*30 months after clearing.

Source: Sanchez *et al.* (1982)

In the fertilized plots, fertilization rates based on initial soil tests resulted in adequate yields until the second year when continued K fertilization without any Mg fertilization further exaggerated a Mg deficiency. Also, the hydrated lime used had a shorter than expected residual effect. After these constraints were identified by soil tests and corrected, grain yields increased and have remained stable (Figure 2).

Soil chemical properties were improved by continuous cultivation in limed and fertilized plots (Table 3). After 8 years and 21 crops, topsoil pH increased from 4.0 before clearing to 5.6; exchangeable Ca increased by 20-fold (as a consequence of lime applications); available P increased from below the critical level of 10 ppm to substantially above it; and Al saturation decreased from high levels to minimal amounts. No significant changes in extractable K, Mg, or Zn were observed. In addition, the 15 to 50-cms layer of the subsoil has undergone significant increases in exchangeable Ca and Mg and a decrease in Al saturation, which is likely to promote deeper root development and thus attenuate water stress during drought periods (Figure 3).

Low Input Soil Management Technology

Need for low-input continuous cultivation. The low-input soil management technology is used because the high-input soil management relies on the use of machinery (rotovation) for the incorporation of lime and fertilizers; the use of high rates of fertilizer and lime, and manual labor for weed control. Although this system is economically viable, the local farmers still show a low degree of acceptance. For this reason, the Tropical Soils Program initiated a new series of experiments aimed at developing a low-input continuous-cropping system. It consists of reducing tillage, recycling residues, using cultivars and species adapted to suboptimal soil conditions, lower fertilizer rates, cheaper or alternative sources of fertilizer, and the judicial use of chemical herbicides.

Preliminary results. Data from a tillage, residue, weed control, liming, and potassium fertilization experiment conducted by Piha (1982) are presented in Table 4. After two crops, he found no response to tillage and that a no-tilled, residue-recycled system is the least expensive because it has a low labor

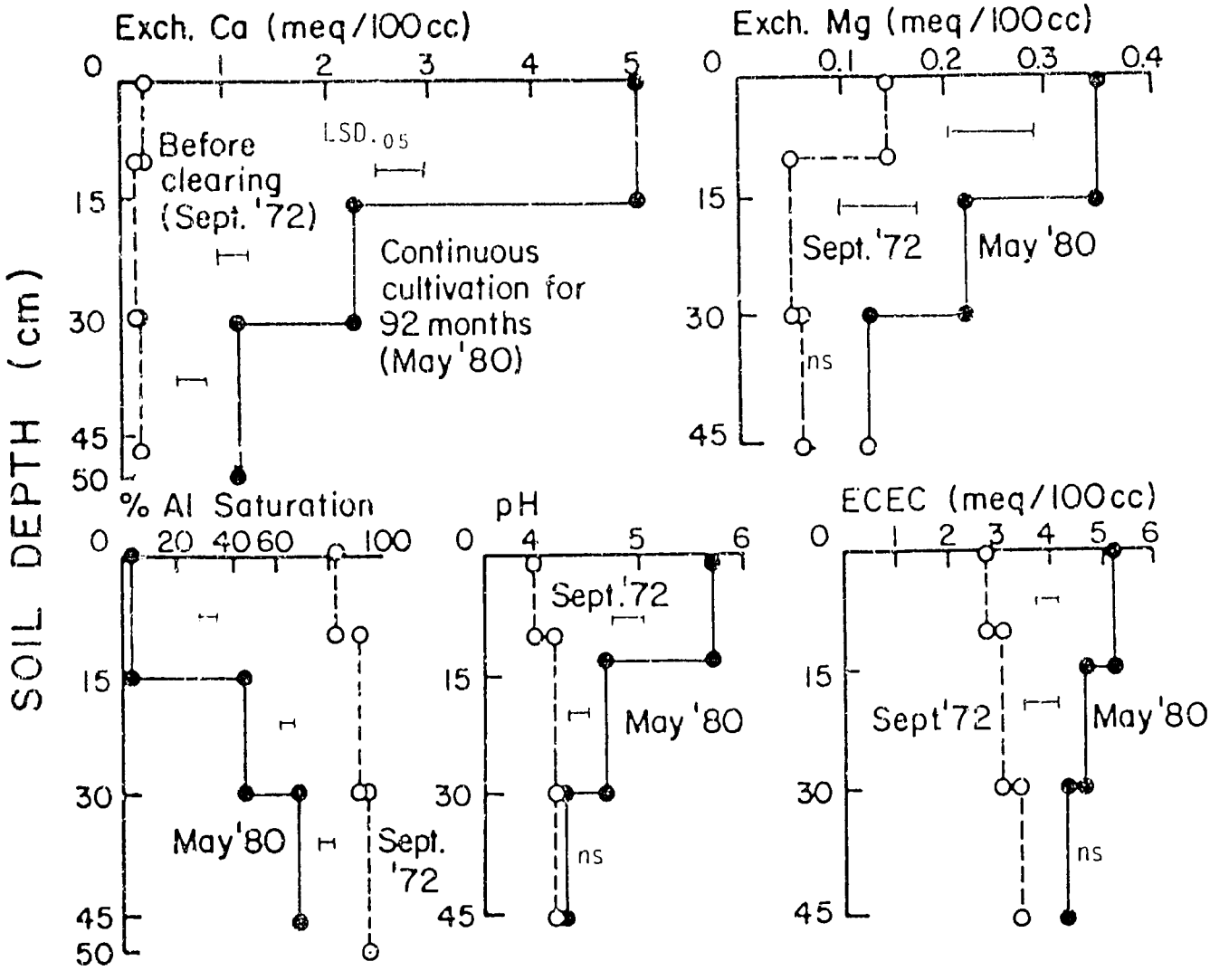


Fig. 3. Chacra 1 - Complete fertilization effects on subsoil properties.

Source: Bandy and Sanchez (1982)

requirement. Thus, he considered this the most suitable system. He also used aluminum tolerant germplasm and found no response to fertilizer in the second crop. Research is continuing.

WEED MANAGEMENT FOR CONTINUOUS CROP PRODUCTION

The results of the field experiments at the Yurimaquas Experiment Station show that weed control is critical and must be accepted by the producer if permanent agriculture is to become a reality. Weed growth is luxuriant due to high temperature and frequent rainfall. Furthermore, the frequency of rainfall during certain periods of the year make weed control difficult. At least four hand cultivations are necessary during the rainy season for weed control and two weedings are usually required in the drier part of the year.

Table 4. Yield Data for the Second Crop (Vita 7 cowpea), Yurimaguas, Peru, 1982

treatments	grain yield (t/ha)
Residues recycled, O K (All tillage systems combined)	1.79
Residues recycled, 60 K (All tillage systems combined)	1.67
Residues removed, O K (All tillage systems combined)	1.72
Residues removed, 60 K (All tillage systems combined)	1.89
Residues removed, 60 K + Lime (All tillage systems combined)	1.79
No till (All treatments combined)	1.73
Strip till (All treatments combined)	1.76
Rotovation (All treatments combined)	1.78
Residues incorporated (All treatments combined)	1.83
Residues burnt (All treatments combined)	1.70

Note: No statistically significant differences in grain yield. No-till residue recycled system is the least expensive and has a low labor requirement.

Source: Piha (1982)

Most of the farmers now accept the necessity of weeding more than once per crop; but the importance of weeding at the correct time is another matter. For example, yield reductions from 41% to 100% would be the result of weed competition if the first handweeding was delayed (Madrid et al, 1972).

Table 5. Weed Survey at Yurimaguas, Peru

A. Weeds present in cultivated areas (corn, peanuts, soybeans)	
Annual grass weeds	
tickle grass	*Panicum trichoides*
goosegrass	*Eleusine indica*
large crabgrass	*Digitaria sanguinalis*
natal grass	*Rhynchelytrum repens*
Annual broadleaf weeds	
groundcherry	*Physalis angulata*
nurui	*Phyllanthus niruri*
pigweed	*Amaranthus spp.*
common purslane	*Portulaca oleracea*
dayflower	*Commelina diffusa*
speedwell	*Veronica spp.*
tall purslane	*Talinum paniculatum*
Perennial grass	
sour paspalum	*Paspalum conjugatum*
West Indian foxtail grass	*Andropogon bicornis*
guineagrass	*Panicum maximum*
slickgrass	*Homolepsis aturensis*
Sedge	
common sedge	*Cyperus diffusus*
B. Weeds present in pastures	
Tall weeds	
"ocuera"	*Eupatorium macrophyllum*
"chisea"	*Eupatorium odoratum*
Short weeds	
"mat pasto"	*Pseudolephantopus spicatus*
arrow leaf sida	*Sida rhanbifolia*
cutting sedge	*Scleria pterota*
C. Weeds present in Cassava	
blue morningglory	*Ipomoea congesta*

Source: Lewis (1979)

Current Research

Weed survey. Table 5 lists weeds identified in the Yurimaguas area. The most common weeds observed in maize, peanuts, or soybean are *Panicum trichoidea* (tickle grass), *Eleusine indica* (goosegrass), *Physalis angulata* (groundcherry), *Phyllanthus niruri* (niruri), and *Talinum paniculatum* (tall purslane). *Bidens pilosa* (spanish needles) is usually present when cassava is grown.

Preliminary experiments. Studies were carried out by Piha (1982) to determine which herbicides and rates should be used to control the existing vegetation in a two-months secondary forest. The weed population consisted of the following: 37% cyperaceae, 24% broadleaf perennials (tree regrowth); 18% broadleaf creeping types; 6% annual broadleaves; 9% annual grasses; 3% musaceae; 3% perennial grasses. Table 6 summarizes the results. Glyphosate showed the best control, but was too expensive. Overall, the most economical treatment was first to slash the vegetation near weed flowering time, then wait 10 days for regrowth and apply a mixture of paraquat with 2,4-D, and finally, one weed later, apply the same mixture as a localized "touch-up" treatment. Any escaping weeds (i.e., tree regrowth and Musaceae) are then controlled by machete. It can be considered very fortunate that the Cyperaceae weeds (mainly *Scleria pterota*) could

Table 6. Preplant Weed Control: Preliminary Studies in Yurimaguas, Peru

herbicide	recommended rate (l/ha)	weeds controlled	cost (US$/ha)
Glyphosate	3	all except some broadleaf trees	90
Bentazon	6	Cyperacae only	66
Paraquat	2	Cyperacae, annual grasses and broad-leaves	20
2,4-D	1	Most creeping and annual broadleaves	5

Source: Piha (1982)

be effectively controlled with a relatively cheap contact herbicide such as paraquat. It was also interesting to notice that the mixture of a contact herbicide (paraquat) with a systemic herbicide 2,4-D in the same tank did not affect the performance of either chemical.

Piha (1982) later recommended a preplant weed control using 2.5 liters of paraquat plus 1.2 liters of 2,4-D per ha (i.e., U.S. $32 + 5 man days/ha.). Due to the ineffectiveness of herbicides against tree regrowth and Musaceae species, manual control was considered the most appropriate weeding system for follow-up weed control. This took only 10 man days/ha and thus the total cost for weed control was $62 ($32 for herbicides and $30 for labor). Besides being cheaper, this method requires less labor, avoids loss of nutrients via weed removal, and gives better weed control.

Weed control in upland rice. Piha (1982) compared the weed competitiveness of the traditional type of rice with a dwarf variety. Close spacing is one of the best ways to improve competition against weeds, but traditional varieties cannot be grown at close spacing due to lodging susceptibility. The question whether traditional varieties at close spacing offer better weed competitiveness than dwarf varieties at close spacing needs to be evaluated.

In practice, it has been noticed that manual weeding between closely spaced plants is very tedious due to the necessity of avoiding the crop plant. Farmers' fields are always infested with weeds at harvest time due to the fact that only one early handweeding is practiced. A later weeding would probably improve yields, but apparently most farmers consider this uneconomical. The tall weeds usually present at harvest would be a serious disadvantage to dwarf varieties. To produce a satisfactory crop of dwarf rice, two hand weedings would be necessary, which means that the production costs would increase.

When tall rice is grown at wide spacing, a directed application of paraquat at about 60 days has been found to be a very cheap and effective way of controlling late weeds without seriously affecting yields. This control method costs about one-fourth of the cost of a handweeding, and is much cheaper than an application of a selective herbicide, such as propanil. Damage to the rice crop

is usually slight and this weed control method requires further evaluation, but it would undoubtedly only be applicable where the rice is tall and widely spaced.

TECHNOLOGY VALIDATION IN FARMER FIELDS

The true test for any improved technology for continuous cropping in the Amazon Basin is its acceptance and utilization by the target group--the shifting cultivators.

First-year On-farm Research

Methodology. Demonstration plots were established in shifting cultivators' fields within an 80-kilometer radius of Yurimaguas on 11 site locations situated on soils tentatively classified as Typic and Aquic Paleudults, Typic Tropudults, Typic Tropudalfs and Vertic Eutropepts.

Three crop rotations consisting of three crops planted one after another within a year, as shown in Figure 4, were tested under three levels of input in each of the site locations. The three systems are: 1.) traditional; 2.) improved agronomic practices without fertilizer or lime; and 3.) improved agronomic practices with fertilizer and lime.

J	A	S	O	N	D	J	F	M	A	M	J
CORN				PEANUT				CORN			
PEANUT				RICE (tall)				SOYBEAN			
SOYBEAN				RICE (short)				PEANUT			

Fig. 4. Crop rotations used in the Yurimaguas small farmer extrapolation program. Source: Bandy *et al.*, (1980).

The traditional system is the way each farmer has always cultivated his land, using his own seedstock when available. System 2 is an improved agronomic practice system utilizing better varieties (when available), correct plant spacing and population, weeding, and application of pesticides when needed. System 3 uses the same improved agronomic practices as system 2 plus the use of lime and fertilizer.

Table 7. Fertilizer Requirements for Continuous Cultivation of 3-crop-a-year (rice-corn-soybeans, or rice-peanuts-soybeans) on an Acid Ultisol of Yurimaguas

input*	rate	frequency
Lime	3 tons/ha	once per three years
N	60-100 kg N/ha	rice and corn respectively, split applied
P	25 kg P/ha	per crop
K	100 kg K/ha	per crop, split applied
Mg	25 kg Mg/ha	per crop, unless dolomitic lime is used
Cu	1 kg Cu/ha	per year or two years
Zn	1 kg Zn/ha	per year or two years
B	1 kg B/ha	per year or two years
Mo	20 g Mo/ha	mixed with legume seeds only

*Ca and S requirements are satisfied by lime, simple superphosphate, and Mg, Cu and Zn carriers.

Source: Nicholaides, et al. (1982)

The Yurimaguas fertilization schedule (Table 7) was modified to a general application of one ton of lime $CaCO_3$-equivalent per year, 60 kg N/ha for rice and corn only and on a per crop basis, 35 kg P/ha, and 22 kg Mg/ha, as adjusted

by on-site soil tests. Some soil chemical characteristics after the traditional slash-and-burn system of land clearing, but before planting of the first crop, are shown in Table 8. Economical analysis of the results was performed.

Yields. Average crop yields of eight farmers' fields for the four crops, corn, peanuts, rice, and soybeans planted in three rotations and under three production systems are shown in Table 9.

Table 8. Some Soil Chemical Properties from the Eleven Chacras Sampled After the Burn but Before First Planting (soil depth 0-15 cms) Yurimaguas, Peru, 1978

chacra location	no.	forest fallow	pH	KCl-extractable Al	Ca	Mg	Mod. Olsen P	organic carbon
		(yrs.)		(--meq/100cc--)			(ug/cc)	(%)
Low exch. Al:								
Km. 15	1	4	5.7	0.2	8	1	6	1.7
Puerto Arturo	4	1	6.6	0	35	5	5	3.1
Km. 8	5	10	6.2	0.2	20	2	9	3.6
Km. 22 (A)	6	4	6.3	0.1	2	1	7	0.8
Apangurayacu	7	1	6.0	0.1	34	8	10	2.2
Sapote	8	6	6.7	0	22	3	15	2.5
Km. 28	9	7	6.5	0	14	2	13	2.3
High exch. Al:								
Munichis	2	8	4.7	1.7	8	2	10	3.2
Callao	3	4	4.3	3.5	2	1	9	1.8
Shucushyacu	10	8	4.5	1.7	6	1	7	2.3
Km. 22 (B)	11	8	4.5	3.1	2	1	13	1.9

Source: Bandy, et al. (1980)

Using lime and fertilizer, individual crop yields were similar to those obtained at the Station (3 tons of rice per ha, 4.5 tons of corn, 2.6 tons of soybean, and 1.8 tons of peanuts). With lime and fertilizer, accumulative corn-peanut-corn grain yield ranging from 7.5 to 11.4 tons/ha was obtained, while yields from the same rotation under the traditional system ranged from 3.5 to 5.3 tons/ha.

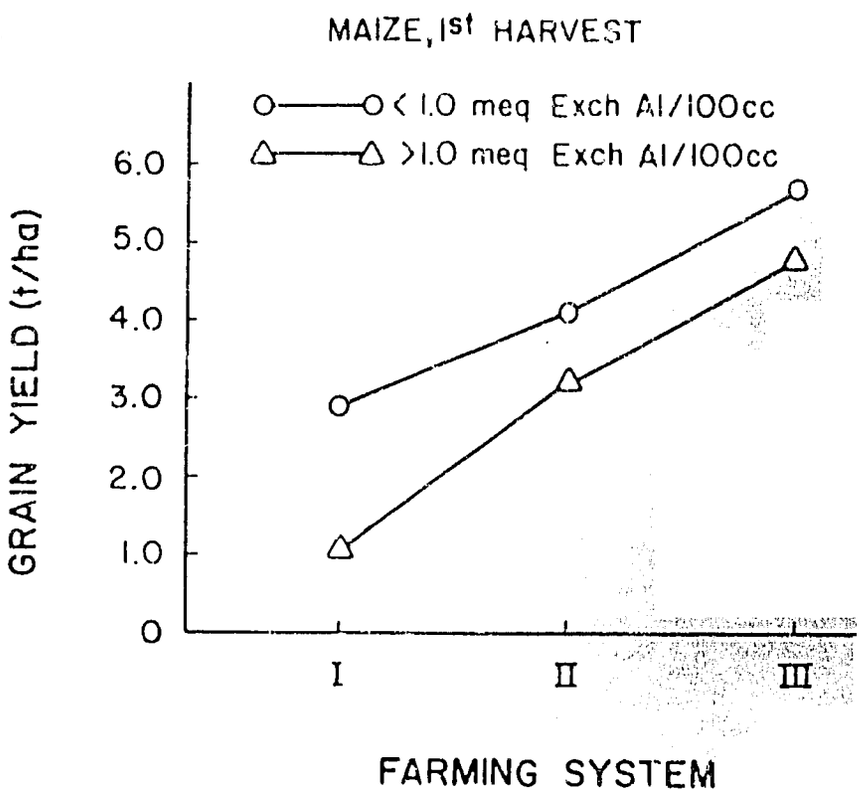
Effects on soil properties. Soil analysis after three consecutive crops on the traditional system revealed nutrient depletion due to crop removal and leaching (Table 10). On all farms, soils had become more deficient in P and more acid (higher exchangeable Al lower and Ca + Mg). This nutrient depletion was reflected in a decline of corn yields in the corn-peanut-corn rotation. As the nutrient depletion became more severe in the second year of the trials, yields declined even further in the traditional system while they were maintained in the improved system with lime and fertilizer (Figure 5).

Economic analysis. An economic evaluation was made assuming limited resources, restricted capital, labor, and work output of the small holder farm family at all possible levels and combinations. For the limed and fertilized corn-peanut-corn rotation, the analysis showed that a farmer with 1.45 ha of land, U.S. $180 of capital ($90 of his own and $90 borrowed at 68% annual interest rate), and a 7-member family labor pool could realize a net farm income of $2,797/year (Nicholaides, et al., 1982). That net income is considerably higher than the current small farm income of U.S. $750 in the Yurimaguas area or the $1,500 net income of the top 25% of the families in the slums of Lima (Nicholaides, et al., 1982).

Farmers acceptance. Although the corn-peanut-corn system is economically viable, the local farmers still have a low degree of acceptance (Figure 6) as the required inputs are too high. The farmer's immediate interest is rice. We must deal with this potential receptivity to alternative methods of successful rice production in order to gain their confidence in trying more complex approaches associated with continuous cultivation. The major problem, once soil constraints are attenuated, is weed control in rice. What herbicide should be applied at what rate and when? The 1978-1979 extension experience has

Fig. 5. Corn yield response to farming system and exchangeable aluminum content for (A) first planting after clearing and (B) third planting after clearing. Yurimaguas, 1979. Source: Bandy et al., (1980)

A.


MAIZE, 1st HARVEST
< 1.0 meq Exch Al/100cc
>1.0 meq Exch Al/100cc
GRAIN YIELD (t/ha)
6.0
5.0
4.0
3.0
2.0
1.0
0
I
II
III
FARMING SYSTEM

B.

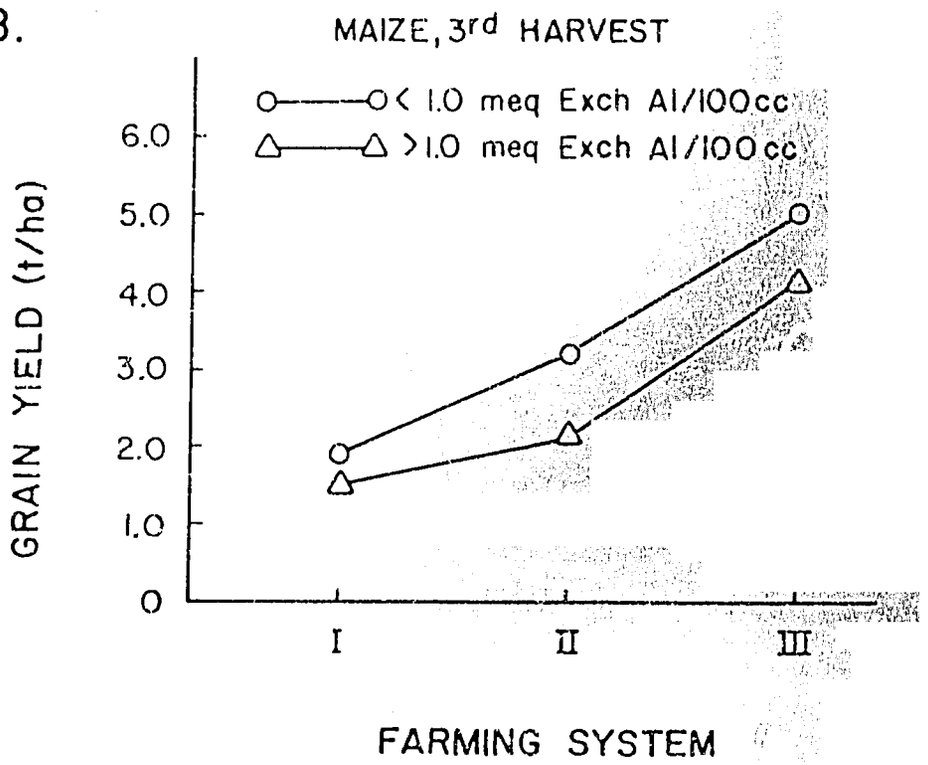

MAIZE, 3rd HARVEST
< 1.0 meq Exch Al/100cc
>1.0 meq Exch Al/100cc
GRAIN YIELD (t/ha)
6.0
5.0
4.0
3.0
2.0
1.0
0
I
II
III
FARMING SYSTEM

Table 9. Grain Yield Results, Extrapolation Trials Around Yurimaguas (mean of eight farmer fields)

crop number	crop rotation: corn, peanut, corn	peanut, rice, soybean	soybean, rice, peanut
	(t/ha)		
First	4.8	1.6	2.3
Second	1.6	3.9	2.0
Third	4.1	2.8	2.2
Total	10.5	8.3	6.3

Source: Bandy *et at.* (1980)

Table 10. Some Soil Chemical Properties from the Remaining Eight Chacras, Sampled After the Third Crop Harvest (12-14 mos.) in System I only (soil depth 0-15 cm) Yurimaguas, 1979

chacra location	no.	forest fallow	pH	KCl-extractable Al	KCl-extractable Ca+Mg	Mod. Olsen P	organic carbon
		(yrs.)		(--meq/100cc--)		(ug/cc)	(%)
Km. 15	1	4	4.8	3.5	4.4	1	0.95
Km. 8	5	10	5.5	0.3	20.1	1	1.51
Km. 22 (A)	6	4	5.4	0.6	1.4	2	0.57
Km. 28	9	7	5.9	0	18.5	2	1.89
Munichis	2	8	4.3	7.6	7.2	5	1.54
Callao	3	4	4.2	11.1	1.1	3	1.31
Shucushyacu	10	8	4.2	4.7	3.5	6	1.07
Km. 22 (B)	11	8	4.4	5.4	2.0	5	1.57

Source: Bandy, *et al.* (1980)

allowed, in spite of its short duration, to transmit the following simple message to the small farmers in the region: "More than one crop after clearing is possible if you use fertilizer, control weeds, and use other acceptable agronomic practices."

Current extension program in Yurimaguas

The 1978-80 extension experiences with test plots showed that, in the second year, considerable pressure developed to get involved with increasing numbers of farmers, schools, etc. to the point that in some cases extensionists' contacts with the farmers were not sufficiently frequent to meet the farmers' satisfaction. The present program must be guided carefully to be sure that there is a margin of extra time and resources in case of unusual bad weather, travel problems, budget restrictions, etc.

The following demonstration plans are tentatively outlined to be initiated in January 1983:

A. Select "suitable" sites of about .5 ha, as uniform as possible, with slopes up to about 6% are acceptable, but trying hard to avoid a plot having concave positions within the area. The demonstration is to begin after the first crop of rice has been grown by the farmer following his clearing of the fallow.

B. A second rice crop will be planted approximately in January after the farmer harvests his current crop. To minimize possible insect and disease hazard of a second crop of rice, we propose that the first-crop rice residue be burned, but good burns are difficult in January because of the rainy weather.

C. Based on soil analysis and previous research results, as well as general information, decide the appropriate fertilizer rate for a second rice crop and apply the fertilizer according to the best information available.

D. Apply the most effective and potentially farmer-acceptable herbicide program for weed control in rice, being careful to minimize the build-up of weeds for future cropping. Apparently most farmers place insufficient emphasis on the potential of weed seed build-up because they do not intend to use the field for future annual cropping.

A proposed method is to slash the straw of the original rice crop, then wait 10 days for regrowth and apply a mixture of 2.5 liters of paraquat plus 1.2 liters of 2,4-D per ha. Finally, one week later, apply the same mixture as a localized "touch-up" treatment. Any remaining weeds (i.e., tree regrowth and Musaceae) are then controlled by machete.

E. We will leave a portion of the area (approximately 20%) without fertilizer. If we are correct, the yield in this second crop after clearing will be reduced in the areas without fertilizer; the objective of leaving this check area is to provide evidence to the farmer that a successful second-crop was made possible by the fertilizer application.

F. In the entire plot, the best technology as to variety, plant spacing and all other cultural practices will be used. If the individual farmer prefers, a varietal comparison will be imposed. We would prefer to avoid any other form of intermediate technology, such as partial fertilization, for the sake of communicating a simple message, i.e., "The use of fertilizer and a general package of good practices make more than one crop possible. This is easier and more profitable than your present program which requires much labor and cost in clearing a new area for rice each year."

G. For the third and forth crops we will be closely guided by the outcome of present research (Piha, 1982; Gichuru, 1982). Probable crops following rice harvest will be cowpeas or peanuts and then a third crop of rice.

H. In this effort, we tentatively plan to use no lime due to the fact that the crops used have been chosen for having good to moderate tolerance of soil acidity. Also, factors are the costs, the logistical transport

problems, and probably need for incorporation of the time in order to achieve rapid return to that investment.

I. For this project, we intend to avoid any tillage other than the tacarpo (planting stick), the finger-like hoe being used presently in Piha's work, or possibly a modified hand tool to make two holes for planting seed and placing fertilizer separately. This "improved tacarpo" would have to work satisfactorily where roots and stumps are present. Minimal soil disturbance will be the goal. Presently, no use of motorized equipment for the preparation of land to permit mechanical tillage is intended until about the end of the second year. All of this has the goal of increasing the acceptability of the practices to farmers.

Piha (1982) and Gichuru (1982) report that the clearing of stumps and roots from a new clearing of heavy timber so as to permit rototiller operation costs a labor equivalent to U.S. $290 per hectare. While this amount is equivalent to only about one ton of rice/ha, and in the long run would undoubtedly be profitable for long-term continuous cultivation, it is fairly easy to understand that this concept is too drastic to be immediately acceptable to most farmers at the present time. If we are successful in getting three or four crops from the plots (rice, rice, cowpeas, rice, [peanuts?]) then the majority of the wood will have rotted away and mechanical tillage, lime incorporation, and full-scale technology may be an option acceptable for demonstration by extensionists.

Obviously, additional station research to support the extension of all aspects of fertilizer rates and placement, as well as other cultural practices for the cropping system proposed above, would be very desirable, except where the information is already clearly available. Piha (1982) and Gichuru (1982) report that fertilizer placement directly under the row using the curved, finger-like hoe cost 20 man-days/ha (U.S. $46/ha). They feel that this form of placement (in a hole made by the tacarpo), or something similar, is worth the trouble because this tool is more familiar to farmers. In view of the present limited acceptability to farmers of the whole concept of fertilizer use, it is important to have sound information

as to the minimum degree of fertilizer incorporation required for efficient plant response to this practice.

J. We must heed the results of considerable Yurimaguas data which shows that continuous rice cropping will be disasterous because of insects and diseases; that generally a heavy mulch is detrimental to rice yields; that legumes rotated with rice appear ideal (rice/cowpea, rice/peanuts, rice/soybeans).

K. There are strong suggestions that this demonstration program consider two options after the second crop of rice:

1.) As proposed above, with cowpea, peanuts (if calcium is applied and digging is feasible) or corn (if lime is applied together with adequate P, K and N; all of these assume some repeated fertilization.

2.) A low input system with little or no fertilization after the second rice crop. The plot would be planted with a kudzu fallow for a few years and then repeated cultivation with fertilization would be promoted. Alternatively, a crop of cassava and/or plantains could be grown with abandonment of the plot to forest or kudzu fallow afterward.

L. We must also work toward a package of technology for the lower lying, less than well drained-soils. This should be set up for demonstration on farms by extensionists. These areas usually have somewhat higher fertility (although evidence suggests P status is often lower than expected). Non-flooding areas may be the place to emphasize clearing for mechanical cultivation after one or two years, complete lime and fertilization package with tillage for long-term production of corn, rice, soybeans, and perhaps peanuts. Since these areas have little or no erosion hazard and less risk or moisture stress, it is essential that we also emphasize use of them. Also, it is apparent that farmers readily recognize that these soils have higher potential productivity; thus, a somewhat different package of practices for these soils may be readily acceptable by farmers.

M. In addition to all of the above, work on flooded rice is needed. Extension involvement in this should be dictated by priorities as extensionists see them. However, from the standpoint of the Yurimaguas program, we have vested interest in making extension progress in the use of upland soils, as pointed out above.

CONCLUSION

A vigorous research program will be continued at the Yurimaguas site. A definite program of research on weed control should be initiated at the station. This may include selected treatments in on-going experiments, adaptive research, and demonstration plots designed specifically to answer extensionists' questions, as well as plot and facilities organized specifically to provide training opportunities for them. Short-term projects to evaluate potential improvements in harvest techniques for small-scale, hand planting equipment will also be useful.

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THE ROLE OF INTERNATIONAL ORGANIZATIONS IN THE TRANSFER OF TECHNOLOGY IN DEVELOPING COUNTRIES

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INTRODUCTION

By definition, albeit somewhat arbitrarily, developing countries are so classed because of low per capita incomes. Thus, if a developing country is to move up on the scale toward self-reliance, some form of income generation must be developed.

In a few favored countries, income from valuable energy or mineral resources, if wisely invested, can serve that purpose. In too many cases however, such wealth is not distributed equitably, and the majority of populations remain poor, especially when the majority are rural residents. There are a few cases also, where labor is plentiful, ready access to raw materials exists, and government policies promote it, that economic development is achieved through industry and trade. Again, however, economic benefits often do not spread evenly across all segments of the population and many people remain poor.

The conditions just cited are not the rule, but are the exception among the developing countries. Most of the countries in question are dominantly agrarian with 60% to 90% or more of the population dependant upon land and/or water resources for their livelihood. Thus, the principal source of income generation is agriculture, including forestry and fisheries. So, if incomes

are to increase, agricultural productivity, in its economic sense, must be enhanced. That, in the real sense of the words, is agricultural development.

Agricultural development has many dimensions. It clearly includes increased levels of production. This, when combined with sensible pricing policies, means both more adequate food supplies and increased farmer income. It includes other income generating activities as well, both on the farm in terms of hired labor and off the farm in terms of input service and supply systems and in processing and marketing. Also, it impacts favorably on the country's trade balance--reduced imports and/or increased exports of agricultural products.

By all odds, then, the first and central requirement to support agricultural development is increased crop production. In most developing countries, yields are far below the potential of the agroclimatic norm. The opportunity for increased production does exist if solutions can be found.

So, what are the solutions? What roles do international organizations play in finding and using them?

DISCUSSION

Plant growth and development is a natural phenomenon that operates under natural laws. Agricultural science strives to understand those laws as a basis for developing technologies to positively alter plant growth and development. The factors influencing the process can be manipulated in crop production systems through those science-based technologies. This is the first major and essential role for international organizations--the generation and adaptation of technologies to enhance crop production.

Among the international organizations, the principal burden for playing this role, as it relates to agricultural development in developing countries, rests with the International and Regional Agricultural Research Centers and Institutes. This network includes not only the 13 supported through the Consultative Group for International Agricultural Research (CGIAR), but a number of regional ones as well such as the International Center for Insect Physiology

and Ecology (ICIPE) in Kenya, and the Tropical Agricultural Research and Training Center (CATIE) in Costa Rica.

The role of these organizations, as suggested, extends beyond the generation of technologies. Through linkages with national research systems, they play a vital role in delivering those technologies into the country research programs where the critical testing and adaptation work is performed. The involvement of the International Maize and Wheat Improvement Center (CIMMYT) and International Rice Research Institute (IRRI) scientists with those in India was a vital factor in helping capture and bring to fruition the potentials of the plant materials that triggered the "green revolution" in that country. Similarly, IRRI has played a critical role in the work leading to the doubling of rice production
in Indonesia over the past decade.

Beyond the international and regional centers and institutes, other international organizations assist in generating and adapting technologies to developing country needs. The multilateral lending organizations, such as the World Bank and the Regional Development Banks, provide financial resources to assist in building research institutions, in the conduct of research, and in the training of research personnel, as do organizations such as the Organization of Petroleum Exporting Countries (OPEC), and the Organization for Economic Cooperation and Development (OECD). The Food and Agriculture Organization (FAO), the United Nations Development Program (UNDP), and other multilateral technical assistance organization provide such assistance in research and in the training of scientists. The first solution, then, is effective international, regional, and country specific research.

A second solution to successful support of agricultural development is the development of processes and the building of institutions through which improved technologies are used in production and marketing enterprises. The benefits of new technologies flow to agricultural development only when that happens.

There are several dimensions to the process through which new technologies are transferred to use in systems of production and marketing. First, and as suggested earlier, the technology must be tested and adapted within the environ-

ment in which is is intended for application. This includes not only the physical and biological, but the sociocultural environment as well. Factual information concerning the technology must be developed and made accessible to users in readily and easily understood form. Systems for information delivery, follow-up, and problem resolution must be developed and institutionalized.

One general observation from the many attempts made over the past decades to develop and sustain effective extension systems in developing countries, is that they usually have not worked very well. Reasons cited for this include:

1. technologies were not available to extend;

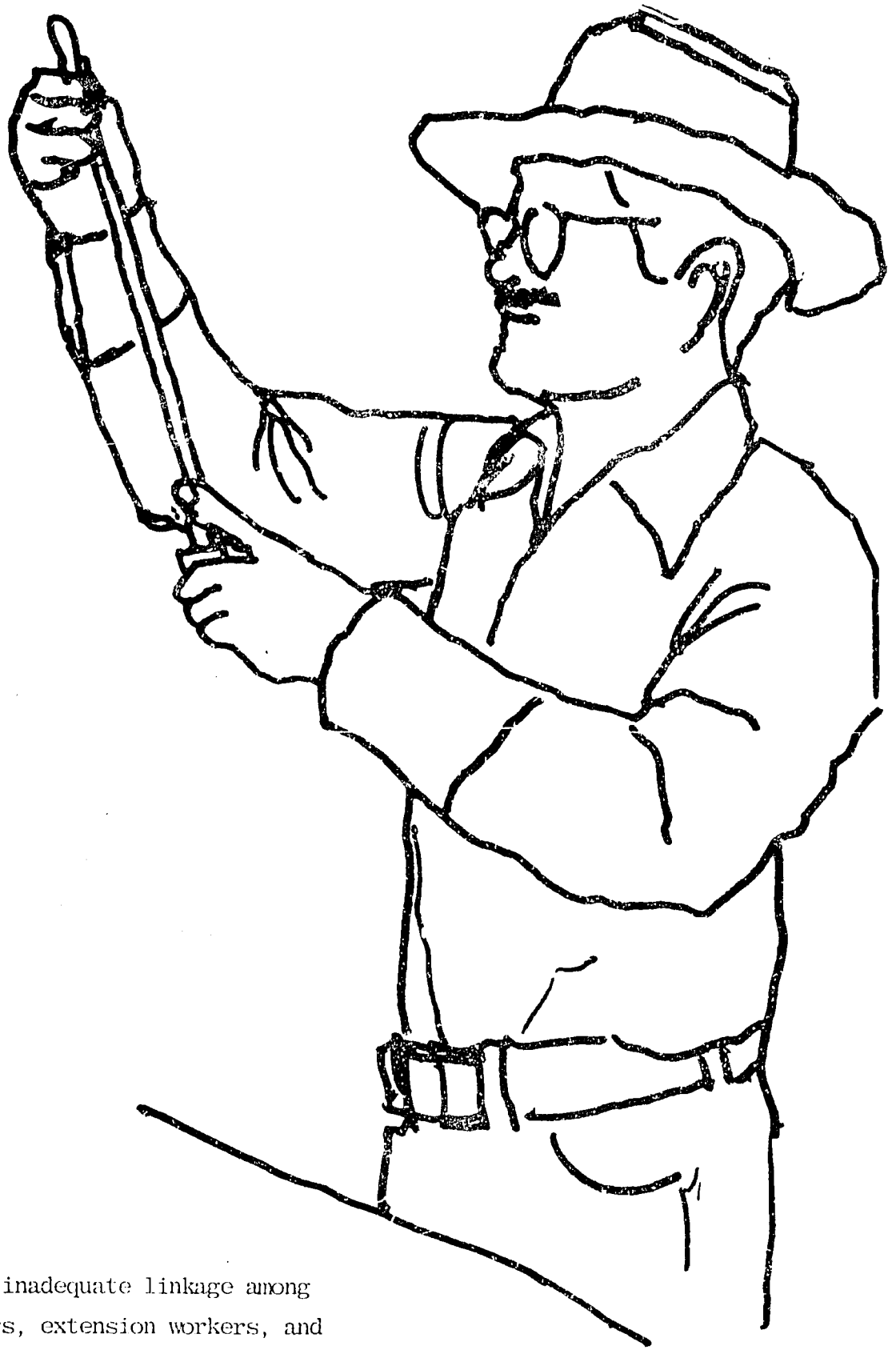
2. government policies failed to provide incentives for applying technologies to increase output, thus generating farmer apathy;

3. extension systems were "weak," extension workers poorly trained, and/or lacked incentive, opportunity, and/or the "tools" needed to do the job; and,

4. weak linkages between researchers and extension workers blocked the flow of information.

There is likely truth in each of these. Others might be cited as well. A growing body of evidence suggests that the root of the problem is the lack of articulation in the technology generation, transfer, use, and feedback system. That is, there often has been inadequate linkage among researchers, extension workers, and farmers to assure a balanced two-way information flow. Too often the flow has been one-way only from the researcher to the farmer. This fails to take account of farmer needs, constraints, and desires.

From this body of evidence has emerged what is referred to as the "farming systems" approach to technology development and transfer. In this approach, the farmer, the researcher, and the extension worker operate as a team in identifying problems, in designing research, and in synthesizing component technologies into production systems that are evaluated in practice by the team in the



"..... inadequate linkage among researchers, extension workers, and farmers to assure a balanced two-way information flow ....."

farmer's field. The farmer thus becomes a full partner in the planning and conduct of the test.

A helpful adjunct to the development of this approach has been use of networks among research and demonstration activities in similar environments. This articulation among researchers permits early and frequent sharing of information and experiences and hastens the adaptive process.

This methodology has emerged from successful experiences in Latin America and Asia. The effectiveness in diffusing rice technologies in South and Southeast Asia through the rice-based "cropping systems" approach and network stands as a most successful example. The "farming systems" approach is increasingly being put to practice in other parts of the world, most notably in Africa.

Training is an important requisite of a functional "farming systems" approach. Practitioners in research and extension organizations must learn how to identify problems, to develop or select component technologies to address them, and to synthesize components into workable systems.

As in the development and adaptation of technologies, it follows that, within a "farming systems" context, the International and Regional Centers and Institutes play a role in technology transfer as well. Working through national systems and networks as in the case of IRRI in the Asian rice experience, full articulation is achieved. And the centers served as an important and useful training resource.

Again, the multilateral organizations fund country and regional institutions and programs for technology transfer. Training both long- and short-term is an important element of that fund support.

A third set of international organizations play a role in transfer of technologies--namely, the private and voluntary organization. This includes quasi-governmental organizations such as the Peace Corps, religious groups such as the Catholic Relief Service, and private associations such as the Cooperative League, USA. Personnel and resources of such internationally oriented organi-

zations are used to deliver known and available technologies to producers in developing countries. Collaboration between such organizations and publicly-supported organizations working in developing countries remains one of the uncaptured opportunities in technology transfer.

Another area to which international organizations contribute is that of information generation, analysis, and synthesis. Such efforts may be descriptive, statistical, or analytical in nature. The information provided may describe and analyze problems, or bring together information helpful in generating solutions. Notable in this type of activity are the global natural resource and climatic assessments and inventories of the FAO, and the country and global agricultural situation reports of the World Bank. These are most helpful in problem identification and in assessing opportunities for technical interventions. Similarly, "situation monitoring" and resulting statistical reports help to better focus efforts on key development problems.

Workshops, symposia, and technical conferences organized and sponsored by international organizations are likewise most useful. These bring together and synthesize the "state-of-the-art" information in problem or subject matter areas. Reports and recommendations from such activities, along with independently developed technical reviews, serve as valuable source materials for researchers and practitioners alike.

Finally, international organizations assist countries to analyze policy and institutional frameworks to support agricultural development. Notable in this area are the efforts of International Food Policy Research Institute (IFPRI) and International Service for National Agricultural Research (ISNAR).

CONCLUSION

International and regional organizations play several vital roles in agricultural technology development and transfer, through conduct or support of research and the development of technologies; through adaptation, testing, and applications of technologies; and through information generation, analysis, and synthesis. These efforts make a valuable contribution to international, regional, and country scientific and technological efforts to help solve the

world's food problem. It will require the best and continuing efforts of all involved in that system if continued success is to be achieved. I hope and trust that this will occur. The world's future--not only in highly developed countries, but the well being of hundreds of millions in developing countries--hinges on the outcome.

THE ROLE OF INDUSTRY IN TECHNOLOGY TRANSFER TO DEVELOPING COUNTRIES

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In the past half century, the agrichemical industry has helped make America a breadbasket of the world. Innovative crop protection technology has been developed and successfully introduced to farmers both at home and abroad where local conditions provide parallel opportunities for new ideas and new concepts.

Now, we hear much about farm and food needs for tomorrow. There is emphasis on increases in world population and increases in food crop demand, especially from developing nations. Industry has considerable practical experience in helping to introduce new farm technology during a period of remarkable gains in yields and farm productivity.

How can this experience be fruitfully directed to the emerging needs of developing countries? That is a challenge we face today. History also suggests it is a challenge that is likely to be with us for years to come. America, after all, had its own long years as a developing nation.

Well known to many of us are the complexities of crop protection in the tropics, where there is now perhaps the heaviest concentration of developing countries. Numerous constraints and problems have already been discussed in the symposium. Still, in considering industry's role in the transfer of crop protection technology to developing countries, it is important to stress that

successful efforts to introduce new concepts must be based on local adaptive research and development.

We cannot expect progress without long-range planning to develop effective crop management systems. We need precise targets and goals, plus a recognition that success and failure may readily depend on seemingly trivial elements, such as when is "the best time" to control a specific weed.

This symposium is naturally focused on weed science technology, a major element in farm progress. Herbicides have become a dominant component in crop protection. Yet, in developing countries an initial priority can obviously involve infestations of plant disease or insects. My examples today highlight various aspects of industry experience in crop chemicals, not herbicides alone.

Great diversity and unexpected size seem to characterize both developing countries and the agrichemical industry: two-thirds of mankind lives in developing nations. In culture and income, societies range form aboriginal to those that are very advanced. There are countries with practical government policies promoting economic and political progress. There are others still in search of such plans.

The agrichemical industry is often conceived to include everything from established commodities (such as fertilizers) to innovative, unique crop protectants. It is an industry that is represented on every continent and in most nations around the world. It is a industry based on sophisticated technology, now making an annual investment of more than $600 million in crop protection research worldwide. But it is also an industry that depends heavily on outside research and development to deliver a useful flow of products to the farm community.

Indeed, farm success with new chemical technology stems from the vital development partnership carried on by industry, university, and government scientists.

In simple terms, then, it has been industry's role to discover and create new agrichemical compounds and to initiate broad development programs that will assure environmental and human safety while evaluating efficacy and farm values of this technology. The satisfactory transfer of this technology, however, has depended on a good economic fit with a local farming need.

Specific local crop studies are frequently critical, and industry's multi-million dollar research and development commitments depend on the opportunity to recoup research costs and earn a satisfactory return on its investment.

It is here that developing countries represent both challenges and opportunities. On the one hand, industry looks for large potential markets for new products to help defray costly research and development. Yet experience indicates it will be many years before farmers in developing nations will find a place for much of today's highly sophisticated technology. Industry must be patient and seek to share only that technology that truly fits, even though it does not include new developments.

In developing nations, the agrichemical industry seeks international trade policies and practices that reflect opportunity and consistency. Here difficulties can arise, sometimes via local administration of import licenses and sometimes because of differences found in patent protection on new technology.

Specific examples trace the complexities and indicate farmer needs for dependability in corp protection. The first example concerns Mexico, where Du Pont has been an active agrichemical supplier for several decades providing herbicides, fungicides, and insecticides for major crops. In 1971, following extensive field trials, we introduced "Benlate," our new fungicide for control of numerous troublesome diseases.

For seven years, Mexican farmers had ready access to Du Pont's "Benlate." Our Mexican colleagues in Du Pont helped to broaden its use via steady development trials and new registrations, plus local formulations geared to Mexican needs. But in 1978, a mexican company independent of Du Pont started local manufacture of benomyl fungicide. Du Pont was immediately excluded from the Mexican market for "Benlate" by denial of an import license.

On the surface, this could look like a successful transfer of agrichemical technology. Really, it underscored the technical problems inherent in making modern chemicals, for the Mexican company has had many production problems. Only inferior quality benomyl is now available to Mexican farmers. The new uses and formulations projected by Du Pont specifically for Mexican use are not being developed. Overall, benomyl is now being used on less than 10% of the crops that would normally benefit from such use. There is severe underutilization of benomyl in Mexican agriculture. Du Pont's expertise on benomyl has been restricted in that country, even though it flows steadily to farmers around the world.

Other developing nation troubles on "Benlate" have appeared in East Africa. Here the fungicide was hailed back in the early 1970's because it controlled critical diseases in coffee, a vital cash export crop in Kenya, Uganda, and Tanzania. But in a few years there were patent pirates at work. In 1981, local African papers reported that a Dutch company had "won a Uganda tender to supply 4,000 kg of the fungicide benomyl, normally produced by Du Pont under the registered trade name 'Benlate'."

The press mentioned that Du Pont's Uganda patent for "Benlate" as being valid through May 1983, but noted that the Dutch benomyl was obtained at prices below those charged by Du Pont. To some observers, this might look like a "Robin Hood" type of technology transfer. But farmers and the local press had a different view when the substitute and substandard benomyl proved ineffective in controlling disease.

A Tanzania paper said: "The (Dutch) consignments have often been found to contain either the wrong ingredient or to have been diluted to the point of uselessness." Kenyans estimated that 10% of the 1979-80 coffee crop was lost. Farmers lost confidence in agrichemical use.

Fortunately, there is a brighter, positive side to the agrichemical story that cuts across our experience with developing countries. We observe intense interest among scientists and the farm community in new compounds and in world-wide trials with these compounds. So we intensify our marketing and information

efforts to help protect our technology, and we maintain our programs and a measure of confidence in Mexico and East Africa despite setbacks.

Local manufacturer of agrichemicals is often regarded as a desirable ultimate goal for developing nations. Two significant examples are Du Pont subsidiaries in Brazil and Colombia that produce both "Karmex" herbicide and "Manzate" fungicide in multi-million dollar plants. The Colombia plant started up in 1963, the Brazil plant in 1966. Both have since been expanded. These plants have created local jobs plus added international trade for each country. The products they make have not only been widely used by farmers in Colombia and Brazil, but also by farmers in neighboring countries of Central and South America. Industry investments have added a new dimension to the local economies of these developing nations.

In addition, these plants and these crop chemicals have paved the way for the introduction of other agrichemicals by Du Pont and other companies. So, many farmers, and the developing nations as well, benefit from the introduction of new industrial technology.

Success in such ventures certainly depends on a continuing product development effort by industry. That is what fits a particular product into local farming patterns at the start, offering gains in yield, quality, and economy to those who adopt the new technology. But product development is a function jointly executed by industry scientists, farmers, and local scientists in the universities and government agricultural agencies. And in effect, the farming community realizes a growing opportunity to evaluate new technology, as it adapts available products to specific needs.

Norman Borlaug has often discussed elements needed for agricultural progress in developing nations. The shortage of trained scientists he cites as the greatest obstacle. But he commonly takes special care to emphasize the great range of the needs for successful introduction of modern farm technology. Crop protection chemicals are a familiar part of the Borlaug equation.

In developed nations where crop yields have surged in the past 40 years, Dr. Borlaug says the private sector has played a major role in the development,

introduction, and distribution of these chemicals, as well as in the development of better application equipment. He looks for an extension of this effort to boost yields in the developing countries.

Industry has intensified its worldwide programs in agrichemicals. The objective is to share our technology where it can be useful and to do so under arrangements that assure protection of innovative developments and products. Developing nations make little progress when they provide a refuge for pesticide pirates.

Yet, with sound programs and dedicated leadership, these nations can set the stage for real long-term gains in agriculture, based in part on the transfer and sharing of crop chemical technology.

TRAINING WEED SCIENCE GRADUATE STUDENTS FROM DEVELOPING COUNTRIES[1/]

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INTRODUCTION

The need for trained personnel in weed science in developing countries of the world is unquestioned. Short-term research contracts funded by the more developed countries may be helpful in improving agricultural systems of the third world, but without trained personnel remaining behind to carry the effort forward, any short-term gains from research contracts will soon fade. Indeed, we all recognize the need, even in the more developed countries, for a strong and continuing effort in agricultural research, extension, and teaching to maintain and improve agricultural production. The premise of this paper is that there must be well-trained and competent agriculturists within the developing countries if there is to be significant long-term improvement in food production. There are several ways to achieve that training, but only formal graduate studies in the U.S. and Canada will be addressed in this paper.

1/ Oregon Agric. Exp. Stn. Tech. Paper No. 6604 and Paper No. 805, Dept. of Vegetable Crops, Coll. of Agric. and Life Sci., Cornell Univ.

Graduate training programs for foreign students are not always as successful as they ought to be, for a number of reasons. Because of the differences in technical experience, professional objectives, cultural background, and language problems, the challenges to a department and to the major professor are often greater than with domestic students. However, the needs are great and, therefore, there is considerable gratification associated with producing competent and well-trained individuals who will return home and contribute to food production in their own way.

We will present ideas on procedures and techniques which may help to improve the training of foreign graduate students. We do not claim to have answers to all questions on this topic, and it is in the spirit of exchanging ideas that this paper is presented.

DISCUSSION

Selection of students. The careful selection of students may be the most important aspect of a successful training program (1). The difficulties involved are many. Unfamiliar grading systems and overly optimistic letters of reference often can mislead us into accepting students unprepared for the rigors of graduate study. How do we know the candidates really want to study weed science? This may simply be an opportunity for ambitious young persons to get away from home and study at a prestigious university. They may not really be interested in weed science or even in food production. The candidates may prefer to wear dress clothes all day and visualize the soft bureaucratic job waiting for them when they return home. How do we know this?

Effort spent in selecting students generally pays off many times over in reduced time later. Talk with appropriate references by telephone, if possible. At least one of the references should have completed some graduate studies at a major university in order to better understand the demands awaiting the candidate. Meet the candidates in person, if possible, and spend some time with them.

Select persons who have already made a commitment to agriculture and weed science. Chances of selecting persons who are genuinely interested in the

discipline are improved if those persons have already worked for a few years professionally and have exhibited a willingness to get their hands dirty in the field.[2/]

Scholastic ability is difficult to assess. Rank in class may be a better indication than grade point average. Unless there is some familiarity with the grading system, a brilliant scholar may have what appears to be a mediocre scholastic record when using our scale of reference. To make matters worse, grading systems change from year to year. Most universities have professionals in their admissions department, or their international office, who can help assess scholastic records. Comparisons with previous students from the same system may also be helpful.

Competence of the student is not the only factor for consideration. The suitability of a particular training program for each student also should be examined. University programs have different philosophies and objectives. Potential students should be advised--clearly and in advance--of the type of program offered and exactly what is expected of them. If a student is primarily interested in physiological studies in the laboratory, he/she should be strongly discouraged from enrolling in a program whose major interest and activity is field research. Information may be requested from the student's supervisor at home regarding the student's future responsibilities, the mission of the employing institution, and specific suggestions for educational experiences to be provided (5).

Sponsoring agencies may not always recognize the extra problems facing foreign students and will sometimes expect them to complete their degree in the same or even less time than domestic students. This attitude often stems from a lack of understanding of the vigor and pace of U.S. and Canadian universities or from the mistaken belief that agricultural training is less rigorous than a classical education. Lack of technical background, difficulties with the

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2/ Borlaug, N.E. Personal communication with second author. August 1982.

language, and the need to adapt to a different educational system make earning a degree in a minimum time almost impossible. We believe that students should not be accepted if their financial support depends on the completion of the degree within a relatively short time.

We cannot over-emphasize that careful selection of students is not only the first, but also the most important step in successful training. Some sponsoring agencies do a fine job of selecting students who have an interest in agriculture as well as the ability to handle the academics necessary for obtaining the M.Sc. and Ph.D. degrees at a first-rate university. However, when selection is poor and we accept a student who does not belong in a weed science graduate program, we subject the student to a traumatic experience. Unfortunately, too often we think of the heavy burden on ourselves as advisors rather than what is happening to the student. Not only are experiences while here damaging, but if we are unable to award a degree, then an even worse trauma awaits the individual upon returning home. In some instances, this may encourage the awarding of a second-rate degree from a first-class institution.

Role of domestic students. Foreign students sometimes are more successful in obtaining financing for their studies than domestic students. Most major professors receive numerous applications from abroad and may be tempted to fill their training programs with foreign students. Nevertheless, a core of competent domestic students can be a significant asset in a training program. They are more familiar with the customs and characteristics of the country and, at least initially, are more skilled in interacting with technical assistants, growers, and extension agents. Domestic students can provide a continuity to the training program and can serve as a bridge to the foreign students, helping them relate to their new educational environment.

English language requirements. Many bright students from developing countries have a poor start in graduate studies because their proficiency in English is inadequate. Most universities require a certain level of achievement in a standardized language examination such as the TOEFL (Test of English as a Foreign Language), as well as the GRE (Graduate Record Examination). These tests are imperfect predictors, but they certainly provide some indication of proficiency in English. If competence in English is a problem after the students' arrival,

"..... careful selection of students is not only the first, but the most important step in successful training".....

there are generally special courses in English available which they should be required to attend. They should be encouraged to use English with family or friends. Often students can gain a considerable advantage by arriving for their graduate studies early in the summer, rather than immediately before classes begin in the fall, so that they are more comfortable in the use of English before class work begins.

Beginning semesters are critical. Arriving directly from a foreign country and being plunged into a rigorous graduate program can be unsettling and traumatic. Adapting to a new language, being introduced to new teaching procedures, making social adjustments, and suffering from general homesickness are problems that any of us could face when studying in a different country. Along with helping to learn the language, early arrival also allows the students to become somewhat adjusted socially before classes begin. Perhaps an even greater advantage is that early arrival permits the students to become acquainted with on-going research, and they can much more quickly make decisions regarding thesis research.

Careful counseling is required at this critical stage. Students often are under considerable pressure to finish their program within a specified time limit. Do not sacrifice the student to such artificial time constraints, but keep the course load at a reasonable level, particularly the first semester. The major professor should be more available than usual for consultation and advice. He should let the student know that someone is available to help at any time.

Individual course programs. As with any graduate student, the course program should be tailored to fit the specific needs of each individual. Usually students from developing countries need a wider and more diversified training program than U.S. or Canadian students. This does not mean a "watered-down" program of elementary courses. A thorough understanding of the interrelationships between a plant and its environment may be as difficult to master as the chemical steps in glycolysis. Designing the best cropping sequence for a given combination of soil, climatic, and economic conditions may require a more astute mind than calculating an advanced statistical problem. Certainly a

broad, flexible program need not be less demanding than a more specialized one. Rigorous courses in soil classification and management, crop culture, plant taxonomy, field plot design, plant pathology, and entomology may be more useful than extensive course work in advanced biochemistry, radio tracer technology, advanced statistics, etc.

Thesis research. In a selection of a thesis topic, emphasis should be on the type of work students are likely to do after returning home. A major objective in a training program should be to provide experiences preparing the weed scientists to return home and efficiently use their experiences in producing more food. The need for basic research in all aspects of science is unquestioned. However, adapting new technology to local situations still requires considerable skill and often will lead to more rapid improvement in food production than if the few well-trained personnel available work primarily on basic questions.

Training in the use of complex and expensive laboratory equipment often is of little value when weed scientists return home. It may actually deter them from engaging in productive applied research. Often students are given the impression that basic laboratory research is required for prestige, resulting in establishing expensive laboratories designed for basic research. This may result in large expenditures of scarce funds which leads to a frustrated scientist, who works on problems of little or no immediate benefit to the country. A weed scientist should, in most cases, work in the field to solve weed problems, not in the laboratory working on the mechanism of action of a specific herbicide. Emphasis then should be placed upon the full understanding of fundamental biological principles and basic agronomic and horticultural skills. This will provide confidence in the ability to return home to conduct a research program designed to improve food production.

On area of weed science sadly neglected in many U.S. training programs is weed ecology and biology of individual species. Whether from developed or developing countries, weed scientists should know the techniques for investigating weeds. Without a thorough knowledge of weeds, weed scientists cannot fulfill their obligations to assist in improving cropping systems. This area of training should receive equal rank with that in biology, agronomy, and other areas mentioned earlier.

The purpose of the thesis is to provide an opportunity to do independent research with guidance from advisors. On completion, it should demonstrate that the student has this ability. Research requires intellectual exercise and emphasis should be on imaginative and creative thinking (3). Too often a thesis is judged, not on its merits, but by the amount of complex equipment used or the current popularity of the subject. However, the method of financing the thesis research can sometimes contribute to this difficulty. Selection of the thesis topic often is dictated by the source of funds available to the major professor. Students may be given a segment of a large, ongoing research project as thesis work and, in essence, become cheap labor. They may write research papers and receive some recognition but, as Kelly (3) indicates, the student may be "cheated out of part of his education--the privilege of learning independently, the exercise of his ingenuity and imagination, and the opportunity to grow and develop intellectually."

None of us prefers to work under budget limitations, but the best training for a foreign student actually may occur when the budget is limited, when apparatus and techniques must be improvised, and emphasis is on intellectual effort rather than on mechanics of turning knobs on the most up-to-date, complicated equipment. In most cases, students will return home to a situation in which the budget is limited. Having access to the best of everything during the training period may not actually be in the best interests of the students in the long run.

At least some of the financial difficulties may be overcome by expecting the supporting agency to provide a modest budget to finance thesis research. The research can then be directed toward the needs of the student rather than the needs of the research project.

An alternative approach to thesis research is for the students to conduct the research in their home country or a third country. This would be practical only if competent advisors are stationed at the research site. For example, scientists at the international centers could be appointed as courtesy professors of the home university and could provide excellent counsel to students. The thesis research would be directed toward a problem important to the students' country, costs would be minimized, and the students would need to spend less time out of country.

Integration of research. Ideally, students should get involved in incorporating their research into a cropping system by working with agronomists, breeders, soil scientists, and economists. For example, suppose a student chooses to study the effect of application time of a certain herbicide within a given crop. Designing the experiment, making arrangements for land and material, and physically making applications and collecting data are all desirable experiences from a training standpoint. But the student must understand that research should not stop there. How does this interact with a grower's schedule? Will it coincide with fertilizer treatments or other pesticide applications? What are the economics of the treatment and can the grower afford to use it? Weed control does not occur in a vacuum. The team approach and integrating research into a workable cropping system should be emphasized.

Extending research results. This leads into a related problem--extending research results to the users. We all know of bright, energetic scientists with files of data which have never been made available. There are no bulletins, no fact sheets, and no journal articles, just a great deal of information which becomes unavailable when the scientist retires. This is especially true in many developing countries where no extension services exists. Research workers often are trained only to do research, and transfer of information to the growers is neglected. For this reason, foreign students should become thoroughly familiar with the philosophy and techniques of adult education systems in agriculture. Time spent traveling with extension specialists around the state may prove beneficial in gaining appreciation for the extension system, as well as being helpful in learning more technology. A good course in extension methods may be helpful. Time spent with a farm family can be enlightening to the student in obtaining a greater understanding of farm technologies, in gaining an appreciation for the use of the extension system as a channel of communication between research workers and growers, and enjoying social contacts in a rural environment (2).

Communication skills. Some research projects in developing countries have failed to progress satisfactorily, not from a lack of technical skill, but rather because the project leader could not communicate clearly with administrators and subordinates. Training in inter-personal relations is difficult, but it is, nevertheless, a critical factor in the success of a program, whether

foreign or domestic. Therefore, competent students who are potential candidates for project leadership in their home country should be exposed to a variety of communication techniques. Leadership requires not only basic skills, but also the development of confidence. This might be accomplished in a number of ways. Seminars, student discussion groups, special speech courses, and membership in such activities as the local Toastmasters Club, may provide experience in a leadership situation.

Teaching experience. The training of a weed scientist in a U.S. or Canadian university generally emphasizes research methods when, in fact, many foreign students will be primarily involved in teaching. Although using an undergraduate class as a laboratory for training foreign students to teach may not always be desirable, teaching methods should receive some attention. Helping to organize a class laboratory, helping to formulate and grade exams, and discussing techniques and philosophies with proven skilled teachers can be valuable experiences.

Professional attitude. In many cases, developing proper professionalism in a trainee is a major challenge. This involves the development of scientific approach including attitude, integrity, and dedication. There is no easy way to provide training in these areas. Attitudes must be conveyed by personal example, by discussion sessions, through contact with other students, or by other means. Perhaps unhurried and uninterrupted sessions during automobile trips while traveling to meetings, off-station research plots, etc., can lead to meaningful discussion beneficial to both the student and the professor.

Krebs (4) illustrates the point that characteristics such as working habits, dedication, and scientific methods can be conveyed from the professor to the student. Krebs, a Nobel Laureate, was a student of Warburg, himself a Nobel Laureate. In fact, three of Warburg's students were Nobel prize winners. Warburg was a student of Fischer, a Nobel winner. Three of Fischer's students won Nobel prizes. Fischer in turn was a student of Von Baeyer, who taught a total of four Nobel Laureates. This scientific "genealogy" can be extended even further (Figure 1). It drives home the point that a close-working relationship between the professor and the student can be very effective in developing professional attitudes and habits.

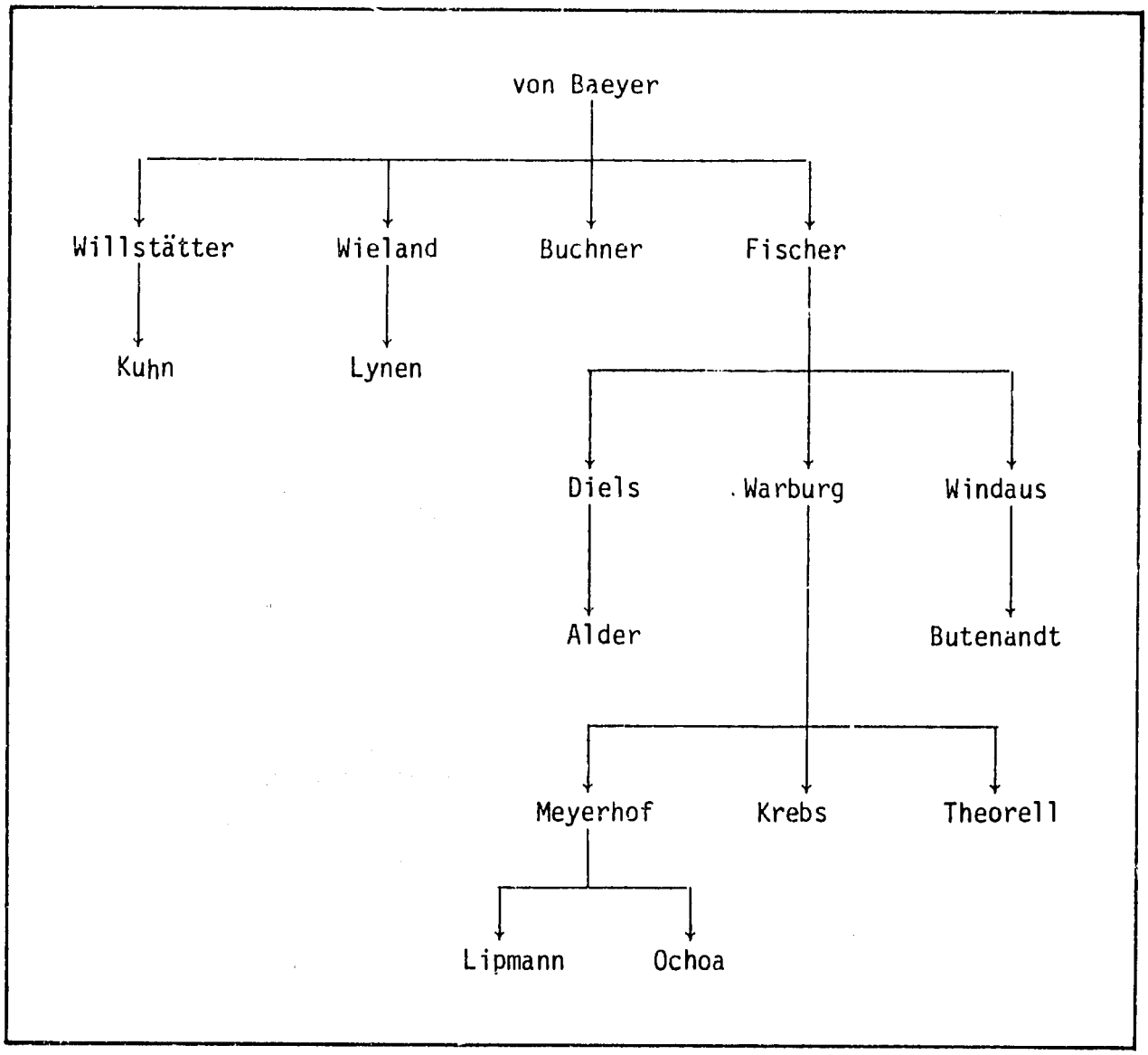

Figure 1. Scientific "genealogy" of von Baeyer's students. The arrows indicate the teacher-pupil link. All members of this "family" are Nobel laureates (4).

Relationship with private industry. Private industry can play a very important role in agricultural development. In many countries, including the U.S. and Canada, commercial concerns are of major importance in conducting research and extension activities. Students should be made aware of how industry can help develop agricultural resources. This might be accomplished by arranging for

the students to spend a week or more with selected industry representatives. They also should be included in planning sessions involving cooperative programs between the university and industry. Private industry is now staffed with personnel who are as well trained and competent as those at the university and the students need to understand that fact. A close-working relationship with industry in the home country may help make the difference between a mediocre and a successful research program.

Evaluation. Each graduate student, foreign or domestic, is constantly being evaluated. If the student is not performing satisfactorily, adjustments are made or the student is asked to terminate the program. The mental ability of a foreign student may be more difficult to evaluate than a domestic student because of language differences, different social customs, etc. Still, we must not fall into the trap of the so-called "double-standards." It is not a kindness to lower standards for incompetent students. This cheapens the degree, not only for the student, but for all other graduates of that university. Even secondrate students often are put into a position of authority at home because of the advanced degree. These people may actually hinder the progress of their home country.

Foreign students are under considerable pressure because failure in the degree program may mean loss of status and opportunities at home. Major professors should do everything possible to assure satisfactory performance, sponsoring agencies should clearly understand that most foreign students cannot be expected to complete degree requirements in the minimum amount of time, and students should be carefully selected by advisors. All of these procedures can help students reach their best potential. But, if a satisfactory level of efficiency and performance is not achieved, the students should be sent home. Poor thinkers and poor workers should not be given a degree just because they are foreign.

Follow-up contact. A critical factor in a weed scientist's success may be a continuing association with the parent university after returning home. This not only helps the weed scientist by keeping abreast of technical aspects, but it also demonstrates to administrators that the scientist is indeed carrying out a meaningful and important research program. Examples could be cited of cases

in which association has not been continued, resulting in a declining productivity, either because of a declining interest on the part of the investigator or because of lack of administrative support. A minimum continuing association could take the form of regular exchange of data and ideas. Personal visits, whenever possible, by a person from the degree-granting institution are most helpful.

CONCLUSIONS

Chances of a successful training program can be improved by careful selection of students, offering sympathetic counseling in the early stages, designing course program and thesis to meet the student's needs, providing opportunities outside the formal degree requirements, and maintaining close association after returning home.

Training students from developing countries can be difficult for the student as well as for the department and major professor. But it also can be tremendously gratifying for all concerned. Many of the world's brightest young people are located in the third world, and unless they can be provided with training and opportunities, they represent a tremendous waste of human talent. Watching this talent blossom and grow can make any difficulties involved seem small in perspective.

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THE SHORT COURSE AS A MEANS OF TECHNOLOGY TRANSFER[1/]

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INTRODUCTION

The weed science short course can be an effective mechanism for technology transfer through dissemination of information in a relatively short period of time. Although these courses can vary considerably in scope, content, and audience, this paper will address details of a commonly held (but perhaps not typical) 2- to 5-weeks course primarily geared to the educational level of a university graduate. The perceived value of such courses will be discussed.

The following comments about weed science short courses are based on my experiences; two courses for the International Plant Protection Center (IPPC) and the National Crop Protection Center (NCPC) in the Philippines, three courses for the Institute of Tropical Biology (BIOTROP) held in Indonesia and the Philippines, and one course for the South Pacific Commission in Western Samoa. In addition, one or two-day workshops were conducted for other agencies. All of these experiences came from Asia and the Pacific.

The need for specialized training in weed science has been expressed by those who have considered weed science needs in developing countries (3,4).

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Training is necessary to provide leadership in instruction, research, and extension in weed control programs, and for other personnel to conduct and assist in research, extension, and training. Furthermore, relatively few weed science courses are taught at universities in developing countries, and if taught, often they are not required.

DISCUSSION OF TRAINING COURSES

Most weed science training courses are similar to, but often broader in scope than, introductory weed science courses taught in universities. Typical topics include weed identification, classification, distribution, characteristics associated with weediness, competition, and other bases for losses. The principles underlying different weed control methods, their usefulness and limitation are discussed. Herbicide topics include: 1.) application and calibration of equipment; 2.) formulations and adjuvants; 3.) uptake, translocation, and factors affecting them; 4.) behavior of herbicides in soils; 5.) crop selectivity; 6.) inherent susceptibility of weed species to herbicides and other practices and resulting shifts in populations/biotypes; 7.) toxicology; 8.) registration/legislation; and, 9.) mechanisms of action and uses of several important herbicide families. The emphasis is on principles rather than specific details.

The state-of-the-art of weed control technology in various cropping systems is presented. Wherever possible, local weed scientists are selected here because they are familiar with the regional practices and cropping systems. Finally, unlike typical university weed science courses, an overview of research methodology is provided. A few simple greenhouse and laboratory experiments are planned and conducted, but field research is emphasized. The goal is to expose the participant to experimentation in weed science.

In all courses in which I participated, a well-planned field experiment best illustrates the activities associated with designing and implementing field research programs. For the two courses sponsored by IPPC and NCPC, a moderately-sized field experiment was conducted with about a dozen herbicides applied at two rates, preemergence and post-emergence to several weeds and several different crops. Participants staked out plots, planted crops, sprayed

herbicides, and evaluated plots qualitatively, sometimes using two rating systems, such as the percent scale and the European system. An overview of statistical methods and hints on typical plot designs were provided. The Field Manual for Weed Control Research (1) provided an excellent reference source for the field aspects. Herbicide selectivity and symptoms are well-illustrated by choosing herbicides with different mechanisms of action. These examples provide a most vivid illustration of herbicide activity and plant selectivity.

Numerous other points often taken for granted by researchers are illustrated to the trainees by actually being involved with every phase of the experiment. For example, the small amount of herbicide required to control vegetation is best learned by measuring and observing the amount used rather than numbers from a calculation pad. The endless problems associated with sprayer calibration, such as rough terrain and wind patterns, are illustrated by a well-planned field practicum.

Timing of field experiences in the course sequence can be critical. If participants are actively involved initially with sprayer calibration, herbicide calculations, and application, they are better able to relate this early experience to materials covered in the course. It will also allow the establishment of the field herbicide experiment in the first few days of the course and will permit participants to follow the experiment during the relatively short 3-week period of the course. This approach is most useful for short courses.

In conjuction with field experiments, another practical phase of the course is the establishment of greenhouse or laboratory projects. These projects can include herbicide wash-off, direction of translocation, and phenoxy volatility described by Burrill, et al (2). Participants working in teams of about five gather background literature related to the project, set up the experiment, take appropriate data, interpret their data, and present and defend their research results to the rest of the participants. This provides added experience in experimentation and gives the participants a feel for every phase of a simple research project.

Thus, these courses are generally much more extensive than a typical introductory weed science course. They are extremely effective in upgrading the level of understanding of weed science concepts and weed research.

In addition to the aforementioned, other techniques are essential to have a successful course. The course organizers must have written material prepared or available for each lecture. This is extremely useful for participants during the course. Where English is not the native language for these participants, written lecture notes or references from leaflets, textbooks, or journal articles provide a tangible foundation for reinforcement of principles presented during the lectures. These lecture notes and other references are sometimes the only source of weed science literature for these participants. Thus, it becomes a most important part of their library, functioning as a vital reference source.

Visual aids should be used when possible. They are extremely effective when the participants are not fluent in the language the course is presented in.

Another useful technique is the presence of as many of the instructors as possible in every formal class period. This gives the participants an opportunity to interact with all instructors as a concept is being presented. Although this active participation is rather time-consuming for the instructors, I perceive it to be worthwhile.

Finally, an examination at the end of the course should be conducted for these short courses. It is not only useful to test the participant's competency in the principles which had been taught, but it also reinforces these principles and encourages the participants to integrate several concepts. Further, a pretest is a helpful device to determine the knowledge base prior to the course, as well as providing a useful outline for the important topics to be covered in the course.

The typical participant has a B.S. degree in Agriculture, some have M.S. degrees, and very few complete diploma programs only. Nearly all have no exposure to weed science in their formal degree coursework. Participants are mainly research assistants, extension workers, instructors at agricultural colleges, and private company representatives.

Feedback from the participants indicates that these courses are quite useful. There is clear evidence that the participants' knowledge of the subject matter improved substantially. This is evident through active discussions as well as quantitative data form pretests and post-tests.

One shortcoming of this type of course is that it does not adequately prepare the participant to conduct research independently, and many who complete the course desire a more advanced course which would prepare them in experimental design and data interpretation. I do not believe that the short course is the way to handle this enhanced research need, but a graduate program would be well-suited for this purpose. Certain institutes, such as the Institute for Tropical Biology (BIOTROP) have a 1-year training course in weed science. In addition to formal lectures and laboratories, this program is highly research oriented, and many of these participants utilize their research as part of their thesis in a degree program from an educational institution.

These short courses might be the most economical way of teaching introductory weed science principles and research methodology to those not previously exposed to weed science. The participants are away from their normal responsibilities for a relatively short period. Instructors participating in these courses are also involved for a short period of time.

Participants probably gain the most benefits in small classes. However, the high cost of conducting these courses for small groups may render small classes unfeasible. The maximum number of participants should not exceed 30. This enrollment would permit interaction among the participants.

SUMMARY OF RESPONSES FROM PARTICIPANT'S QUESTIONNAIRE

In an effort to assess the effectiveness of these short courses, a questionnaire was sent in mid-June 1982 to approximately 60 participants of the 1979 and 1980 3-week IPPC/NCPC short courses held in Los Banos, Philippines. Reply was requested by late July 1982. While only 17 questionnaires were returned, the remarkable similarity in answers led to some general impressions. The topics and responses are summarized below:

1. Extent of participant's involvement in weed science. Six categories of involvement were provided; none, less than 10%, 11% to 25%, 26% to 50%, 51% to 75%, and 76% to 100%. Nine of 17 respondent spend 26% to 50% of their time in weed science efforts. Only one respondent spends less than 10% time in weed science, while two indicate 76% to 100% time in weed science. The respondents

include technical/economics assistants, extension workers, training officers, researchers, assistant professors, and chemical company representatives. This mixture of participants is typical of all short courses that I participated in.

2. Improvement of knowledge in weed science technology. Although different aspects of the course appear most important to the different respondents, they feel that the course has a very positive influence on them. All respondents clearly indicate that the course upgrades their general knowledge of weed science. Many express greater confidence in dealing with issues on weeds, weed control methods, and herbicides.

3. Use of information from the training course. Many are able to establish farmer training programs or research/demonstration trials illustrating the usefulness of weed control practices. These range from comparisons of mechanical and chemical control, minimum and zero tillage practices, to shifting farmer practices from a monocrop system to crop rotation. Some have conducted programs to train technicians, who are responsible for training farmers. Two are assistant professors in crop protection providing weed science instruction as well as advising on weed research projects.

Several respondents cite the importance of the references and notes given during the course as being very helpful in their programs. It appears that these references are the major source of information that many participants now have in weed science.

4. Benefits to the ultimate user. Typical responses are as follows: "The farmers have information from which decisions on weed control methods can be made." "Farmers are using the technology of herbicide application quite effectively in several crops." "Farmers are now considering rotation instead of planting the same crop throughout the planting season." "Farmers are now practicing minimum tillage in soybeans." "The technicians can more effectively train farmers." These responses indicate that technology transfer is taking place.

5. Constraints in use of information. It is difficult to gain perceptions here, although many express problems with insufficient funds and equipment to launch effective programs.

6. Other comments. When asked to provide any other comments describing the usefulness or lack of usefulness of the training course, it is interesting to note that nine of 17 respondents indicate a desire for periodic courses to upgrade their knowledge in weed science. This response is noteworthy since the question was not posed directly.

CONCLUSIONS

Although it is difficult to make conclusions based on this limited questionnaire, it is clear that the courses are enormously beneficial in upgrading the knowledge of the participants. The multiplier effect, or technology transfer beyond the knowledge gained by the participants, appears to have taken place. Furthermore, the increased knowledge in weed science gives the participants a better base to discuss weed science more effectively with colleagues, administrators, and the general public.

Besides the short course described here, the technical content of short courses/workshops can be increased and effectively utilized for weed science professional or administrators. A 2- or 3-day program by top scientists in their fields can effectively update professionals. Thus these "short courses" may take different forms and, when properly implemented, can be effective tools in the transfer of technology.

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EXTENSION TECHNIQUES TO REACH THE FARMER

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INTRODUCTION

The title of this presentation is itself an example of how communications work. I saw that the title of my talk was to be 'Extension Techniques to Reach the Farmer' when I received a copy of the agenda. This is an excellent title which, if I interpret it correctly, means "how to extend information to reach farmers." As you will see, the word extension is especially appropriate.

I should note that we at BASF are well aware of the total commitment required to sell herbicides in developing nations. Not only are there financial questions, there are serious concerns about the proper use and disposition of all chemicals. It is not enough to provide directions for use, especially in areas of high illiteracy, nor is it adequate to explain use directions to a farm worker who is incapable of understanding what you mean. It is necessary for any marketer of agricultural chemicals to build a bridge in communications to the farmers of developing nations--to extend rather than simply provide information. It is this effort which I would like to describe to you. To do so, I feel that we must begin with a basic communications model.

THE ELEMENTS OF COMMUNICATION

The fundamental components of a communications model consist of a sender and receiver. The information flows from sender to receiver. Understanding of

the information is verified by the receiver, who feeds back information to the sender.

There is another element in the communication model called background noise. As the term implies, background noise interferes with communication. Two people talking in a noisy factory have to overcome background noise. To someone listening to a radio program, background noise is called static. Yet background noise is not necessarily audible sound. Visual interference with a television broadcast could also be called "background noise" and, as you will see, cultural differences also cause a kind of background noise of their own.

FORMS OF COMMUNICATIONS

The simplest form of communication is two way, face-to-face communication. More complicated forms of communication involve group-to-group, or even many groups to many groups. The advertising industry is most closely connected to mass communications in the mind of the consumer, but advertisers are relative latecomers to the communications field. Churches, governments, schools, and the family communicated information that had a profound effect on society long before marketers thought of using it. Like these institutions, marketers have frequently been accused of manipulating people through their advertising. In my experience, people feel that they are being manipulated when they disagree with the sender's communications objective. Manipulation, therefore, is mostly a question of perspective. In all cases, the basic steps are the same: you must first capture the awareness of your target audience and then interest them in your message, which should motivate them to think or act in a way that meets your communications objective. This simple sequence is critical to any successful communications effort, but the way in which they must be deployed varies greatly when comparing industrial nations with developing nations.

COMMUNICATING TO THE AGRICULTURAL SECTOR

For comparison, let's first see how communications are used in the U.S. agricultural industry. Here we have 4 million people working on 2.3 million farms with a total value of one trillion dollars. About one million farmers

are the decision makers in this audience and, in 1980, they spent a record $135 billion on materials and services for production. In that same year, marketers spent $500 million in mass media to communicate to this group. This, then, is an excellent example of group-to-group communications.

The normal tools used by advertisers of agricultural products to reach this target audience are: TV, radio, print advertising, direct mail, and printed materials. Of course, the basis for communicating successfully with this target audience is a sound marketing program--but we'll concentrate on the communication aspect rather than marketing.

The methods commonly used to determine the effectiveness of a communications program include: pre-testing, readership studies, attitudinal studies, benchmark (comparative) studies, recognition studies.... The list is endless, and the measurement techniques have become increasingly sophisticated.

Obviously, then, the industrialized nations make a great effort in measuring the effects of communication on consumers, yet there remain many more questions than answers. We must also be concerned that the very level of communications builds resistance among consumers. American farmers are now overly exposed to advertising and they criticize the industry for spending so much money in advertising. In fact, the most recent edition of Agri Marketing magazine[1/] contains a feature story on how major agricultural companies are attempting to overcome this sensitivity. Ciba-Geigy, Elanco, Sperry-Holland, DuPont and even the U.S. Department of Agriculture now have communications programs designed to improve public perception of farming in the United States.

We must have alternate ways of communicating, whether it is through satellites, cable TV, or home computers--we really don't know the answers. So, if we don't have all the answers for industrialized nations, what prospects are there for developing nations?

1/ "The Image Maker," Agri Marketing, January 1983, page 50.

OBSTACLES TO COMMUNICATIONS WITH DEVELOPING COUNTRIES

Let's return to our basic communication model. The element of background noise now becomes an important barrier to communicating with people in cultures that are fundamentally different than ours. Those of us raised in industrialized nations have a perception that we understand the motivations of people with whom we communicate. This perception is not valid if we apply it to people who have vastly different cultural practices. In fact, the mistaken belief that people in developing nations understand us creates a cultural background noise that must be overcome. In order to overcome this barrier, we must recognize the difference between form of communication and the meaning of communication. A friendly wave may be interpretated as a threatening gesture to people of some cultures. The form of communication, a wave of the hand, does not conform to the meaning it has to the recipient. This difference in form and meaning is a critical obstacle to communications with people in developing nations. Although the concepts held by those exchanging information may be identical in form, they differ in context, regardless of the vehicle used.

An example of the difference between form and meaning is the word family. In English and German, the word family, or familie, sound alike and have the same basic meaning; a small unit consisting of parents and children. Form and meaning are alike. In Swahili, the only comparable word is "ndugu." This word means all relations, a much larger unit than what we mean by "family." The form may be similar, but the meaning differs--and communications suffer. At BASF, we worked together with organizations like the Food and Agriculture Organization to overcome those obstacles and improve communications with the people in developing nations.

Another obstacle to communications in these countries is the lack of tools available to reach the audience. In order to achieve effective communications, UNESCO recommends a minimum of the following vehicles for every 100 inhabitants: one newspaper, five radio sets, two cinema seats, and two TV sets. Few developing nations have reached these minimums. Not only do we have the problem of overcoming background noise, we also lack the communications tools needed to reach farmers.

Before detailing some of the alternatives available, I'd like to mention the political ramnifications of the absence of communications tools in developing nations. A few intriguing questions have been raised by Professor Doctor Franz Ronneberger of the F.A. University of Erlangen/Nuernberg:

1.) What is the impact on a developing country of instantly importing the technologies and media systems of the industrial nations?

2.) What is the impact of having total government control of radio and television programs in countries that have no freedom of information?

3.) What effect will there be on the culture of a developing nation when, because of financial limitations, all programming is borrowed from industrialized nations?

4.) What happens in countries where no common culture or language exists?

5.) What will be the impact of the increasing separation of rural and urban areas of developing nations--a difference that could be increased by modern communication tools?

These questions represent the tip of a very large iceberg. The issues are important and should be kept in mind because they profoundly effect all communications within the country.

EXAMPLES OF COMMUNICATIONS WITH DEVELOPING NATIONS

I now have a few examples of how we attempted to communicate with consumers in developing nations. I should explain that I do not intend to sell BASF products to you--you are not the target audience, after all--but I never regret exposing people to our advertising. In fact, I enjoy it. Still, my examples are all from BASF, a coincidence.

We certainly do not claim that everything we have done worked perfectly. The examples I will show seemed to work very well and represent our best efforts at the time.

coordinated the use of billboards with the activities of our technical staff. Wherever the technical people worked in field tests plots, the billboards explained what the product in the test would do. The road signs had removable panels constructed so that different messages could be inserted on the front of the sign. These panels were stored on the back of the sign, and were changed frequently. The billboards became something of a roadside newspaper. Through experience, we learned that the most effective billboards were simple and very visual. In countries where even the most basic construction materials, like wood and cardboard, were difficult to get, we used stencils, paint and a brush. After a while, the signs became a common sight throughout agricultural areas.

A second example shows a colorful, cartoon-style poster used for an agricultural project in Afghanistan. It has no words at all and describes the need for proper soil cultivation and fertilizers. Although fairly simple in appearance, I would say that it is still overly complicated for the target audience.

Another example was developed in Ethiopia where we wanted to teach farmers about the benefits of using fertilizer. We had no idea how to do it, since there were no media to work with. A Norwegian missionary school helped us with the problem. The missionaries asked the children how they would tell their parents what fertilizers do. Their answer was simple: when plants are hungry, they need food. How do we get this message to the parents? The children gave us another idea--use the covers of their school books. We designed the covers with simple illustrations and had our message hand delivered to our target audience.

These were among our earliest attempts in communication. While we were busy trying to educate our target audience, we also learned a great deal ourselves. Our later attempts reflect an improvement in understanding communication techniques.

As a result of a well-directed market survey, we discovered that there was a demand for crop protection products and specialty fertilizers in Morocco, and that the demand was growing steadily as agricultural yields increased. Government agronomists helped us a great deal. We had to inform farmers about the

need to combat weeds in sugarbeets in a way that allowed for tremendous differences in education among the population. In Morocco, our advertising planning was done backwards, with plans adjusted to accommodate differing patterns of behavior.

Films are an excellent communication tool in countries like Morocco, but they must be used carefully. Films produced in industrialized countries cause uneasiness and even resentment in the population of developing nations. All people appreciate an effort to present information in a more familiar environment. In fact, one simple slide can be more effective and more successful than a full length film, so long as that slide shows local scenes. Also, the lack of suitable facilities for showing slides and films--and the inability of farmers to travel--made it necessary to devise ways to bring slides and films to the farmers. When done properly, audio-visual is the best way to train customers in correct product use.

An ideal way to bring the message to the consumers was found in the shape of a trailer. We purchased a trailer with all necessary audio-visual equipment. It was the center of attention wherever it went. Theoretical instruction was supplemented by practical training, examples, and demonstrations in the field. Simple drawings in leaflets distributed to the farmers repeated the story in pictures and provided the farmer with a way of retaining the main idea; he then explained what he had seen to other farmers in his area, thus multiplying the message.

This project was a great success and yielded measurable results. Despite this, the trailer was no panacea. Costs were high, logistical support was complex, and the need for precise planning was critical. The trailer had to arrive in an area at the proper stage of an agricultural test. In addition, invitations have to be sent out and a follow-up visit must be carefully planned. So the trailer concept is not always the perfect answer.

In all cases, we discovered that our developing country consumers responded best to illustrative and symbolic language. We designed leaflets to capitalize on this fact and to allow farmers to consolidate information and pass it on. Rather than using German designers, we tried to find art directors who were

very familiar with the people of the region. We learned a lot about graphic communication from these designers, even though it was not always easy to work with them.

Perhaps the best example of getting close to the target audience is the "magic poster" experiment which we used to train tractor drivers in Brazil in applying crop protection products. This poster has very thin lines illustrating the proper way to care for application equipment. The lines cannot be seen by the audience, but the trainer can see them clearly. We would train a local technician to use this poster, filling in the lines as he went along. When he gave the training information, he would use local language and local examples while still conveying the key points. As a result--simply by drawing over existing lines--the trainer became an expert in teaching local tractor drivers how to apply products safety and maintain the equipment effectively. As always, a leaflet that duplicated the training information was distributed. When the tractor driver looked at the illustrations in these leaflets, he associated them with the explanations provided by one of his local people, rather than with the explanation given by a German company. By doing this, we helped to minimize the background noise in the communication process.

CONCLUSIONS: EXTENDING INFORMATION

The latter examples show how earlier lessons were incorporated and expanded upon. Some of the many lessons learned can be summarized in three points critical to communicating with audiences in developing nations:

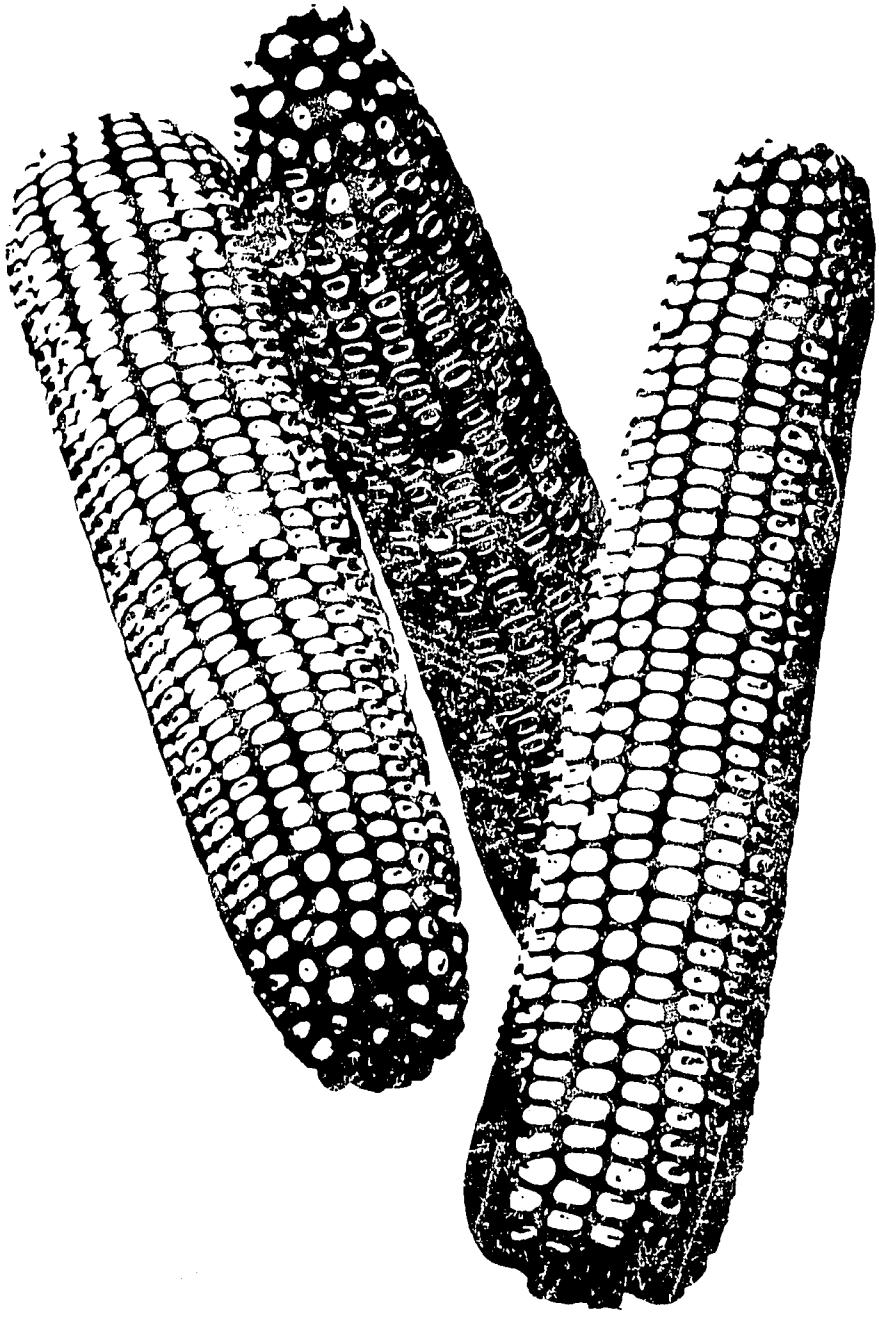
1.) Get close to your target audience by finding people who can communicate with you and with your target audience. This may require more than one person and you may have to ignore the normal social hierarchy, but it is essential that you communicate content, not just forms.

2.) Listen to these people. Do not simply lecture to them. What they have to say is real and very valuable.

3.) Some of the people with whom you communicate will be natural leaders. These leaders are your most important asset, because they can multiply

the impact of your message. Train them to train others. Give them basic communication tools and teach them how to use them.

The essential point of communication is to initiate a process that is self-perpetuating. Find an area of people with similiar problems and an individual capable of translating your solutions to others within that circle. From that point on, communications becomes a chain reaction: the people learn from one another. This is the way to extend information to reach farmers of developing nations.



CONTRIBUTORS

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Professor Fischer attended the University of the Republic of Uruguay, where he received his B.S. degree, and is currently on a leave of absence from University of Chapingo, Mexico, to complete his graduate training at Oregon State University. Professor Fischer has worked as a weed researcher at the National Agricultural Research Institute of Uruguay and on assignments for private industry in Argentina, Brazil, and Paraguay. In Chapingo he is responsible for teaching and research activities in weed science and is very active in scientific societies such as ALAR (Latin American Rhizobium Association), SOMECTMA, Weed Science Society of America, and the International Weed Science Society. Upon completing his training at OSU, he will return to his duties in Mexico.

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Professor Fryer has received M.A. degrees from both Cambridge and Oxford, and is presently the Director of the Weed Research Organization as well as a Visiting Professor at Reading University. He has served as a member on the National Academy of Science Committee on the Effects of Herbicides in Vietnam, as a chairman of the Program Committee for several British Weed Control Conferences and was the first weed specialist for Plant Protection Ltd. Currently, Professor Fryer is the Chairman of the Editorial Board for Weed Research, member of the Board of Management for the British Crop Protection Council, member of the Executive Committee of both the European Weed Research Society and International Weed Science Society, and Chairman of the Scientific Advisory Committee Agricultural Chemical Approval Scheme. He is very active in professional societies including Foreign member of Academie d'Agriculture de France, European Weed Research Society, International Weed Science Society, Weed Science Society of America (Honorary Member), Honorary Fellow Royal Agricultural Society of England, member of the Association of Applied Biologists and Fellow of the Institute of Biology. In 1979, Professor Fryer received both the Otto Appel Commemorative medal for outstanding contribution to research in the field of weed science and the CBE (Commander of [the Order of] the British Empire) for services to the Agricultural Research Service.

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Dr. Johnston attended Cornell University, where he received his B.A. in Government, and Stanford University where he received his M.A. in Economics and Ph.D. in Agricultural Economics. He served as the Chief, Food Branch, Economic and Scientific Section, General Headquarters, Supreme Commander for the Allied Powers in Tokyo, Japan from 1945 to 1948, and as the Agricultural Economist, Food and Agricultural Division, European regional office, Marshall Plan, in Paris from 1952 to 1954. In 1962 he was a Visiting Professor at Makerere University in Uganda and from 1975-1976, at the University of Nairobi. Currently Dr. Johnston is Professor and Economist in the Food Research Institute

at Stanford University. He is very active in professional societies including American Economic Association, American Agricultural Economics Association, International Association of Agricultural Economists and African Studies Association. Dr. Johnson has authored or co-authored several books dealing with the agriculture and economics of developing nations including his recent books "Agricultural Change in Tropical Africa" with K.R.M. Anthony, W.O. Jones, and V.C. Uchendeu (1979) and "Redesigning Rural Development" with W.C. Clark (1982).

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Professor Li attended both the University of Nanking and Yale School of Forestry. Currently he is a Professor of Botany and Head of the Weed Research Laboratory in the Agronomy Department of Nanjing Agricultural College. Professor Li has been teaching botany in agricultural colleges in China for more than 40 years and has been working in the areas of weed biology and weed control since 1953. During that time he has published several textbooks in botany, plant identification and weed control and quarantine. He is very active in scientific societies including the Botanical Society of China, Plant Protection Society of China and International Weed Science Society. Currently Professor Li is the President of the Weed Research Association of China.

Matthews, L. J.

Since completing his degree at Auckland University College in New Zealand, Mr. Matthews has been very active in weed science and plant protection. He has served as Officer-in-charge, Plant Protection, Ministry of Agriculture and Fisheries, and as the Technical Development Officer, Agricultural Chemical Act. Presently Mr. Matthews is the Weed Specialist for FAO and is responsible for improving weed management at country level with specific reference to developing countries and serves as focal point for the development of regional and global programs. He is active in scientific societies and is a Honorary member of the New Zealand Weed and Pest Control Society in which he has served as Secretary to the Vice President and President, and the Asian-Pacific Weed Science Society and Weed Science Society of America. Mr. Matthews is also a Fellow of the New Zealand Institute of Agricultural Science, Past-President of both the Asian-Pacific and International Weed Science Societies and Executive member of the European Weed Research Society.

Nicholson, Ralph C.

Dr. Nicholson has attended the University of Vermont (B.A.), University of Maine (M.S.) and Purdue University (Ph.D) where he is currently an Associate Professor of Plant Pathology and Co-Director of the Purdue Program in International Crop Protection. Dr. Nicholson's research program is in disease physiology and biochemistry with emphasis on corn and sorghum, and the biosynthesis of phenols. He also teaches graduate courses in disease physiology and phenolic compound metabolism. In the context of international agriculture, Dr. Nicholson has collaborative programs with researchers in San Paulo, Vicosa, and Campinas, Brazil and in Faisalabad, Pakistan. With his wife he has taught an interdisciplinary course in problems in agricultural development and international agriculture and in 1979 was co-author of the book Distant Hunger which deals with world hunger issues. He is very active in scientific societies including American Phytopathological Society, Canadian Phytopathological Society, Brazilian Phytopathological Society and the American Chemical Society.

Nishimoto, Roy K.

Dr. Nishimoto attended both Oregon State University, where he received his B.S. and M.S. degrees, and Purdue University where he received his Ph.D. Presently he is Chairman and Professor of Horticulture at the University of Hawaii where he conducts research to develop weed control practices and their integration in to horticultural crop production, teaches a senior-graduate course in weed science, advises graduate students and administers the Department of Horticulture. In 1976-77 he was a visiting fellow at the Department of Vegetable Crops, Cornell University. Dr. Nishimoto has had extensive experience in weed science short courses and has participated as a consultant to help conduct several short courses/workshops on weeds and their control in Western Samoa, Indonesia (twice), Philippines (thrice), Saipan, and Tonga. He is also active in the Asian-Pacific Weed Science Society (current Secretary), International Weed Science Society, Weed Science Society of America, and American Society for Horticultural Science.

Robins, John S.

Dr. Robins attended Kansas State University, where he received his B.S., and University of California-Davis where he received his Ph.D. in Soil Science. Dr. Robins conducted soil and water management research, and supervised and

administered research programs of the Soil and Water Conservation Research Division, Agricultural Research Service in the western United States from 1951 to 1965. From 1965 to 1970, he administered the Washington State Agricultural Experiment Station programs and served as Dean of Agriculture from 1973 to 1978. He was also the Associate Administrator for the Cooperative State Research Service, USDA, from 1970 to 1973. Presently, Dr. Robins is the Agency Director for the Food and Agriculture, Science and Technology Bureau in A.I.D. and as such is responsible for providing leadership and direction to the Agency's service and technology activities in food and agriculture. Dr. Robins is an active member of the American Association for the Advancement of Science, American Society of Agronomy, Soil Science Society of America, Soil Conservation Society of America and Western Soil Science Society.

Sweet, Robert D.

Dr. Sweet attended Ohio University, where he received his B.S., and Cornell University where he received his M.S. and Ph.D. Recently Dr. Sweet retired as Professor and Chairman of the Vegetable Crops Department at Cornell University and presently is serving as Professor Emeritus. During his 38 years in weed science, Dr. Sweet has been very active in teaching, with his first Ph.D. student receiving his degree in 1949. His major emphasis is herbicide evaluation in horticultural crops. In addition, Dr. Sweet is active in scientific societies including the Weed Science Society of America in which he was elected a Fellow in 1974, Northeast Weed Science Society, American Society of Horticultural Science, International Horticultural Science Society, and Sigma Xi.

Tolson, E. Norris

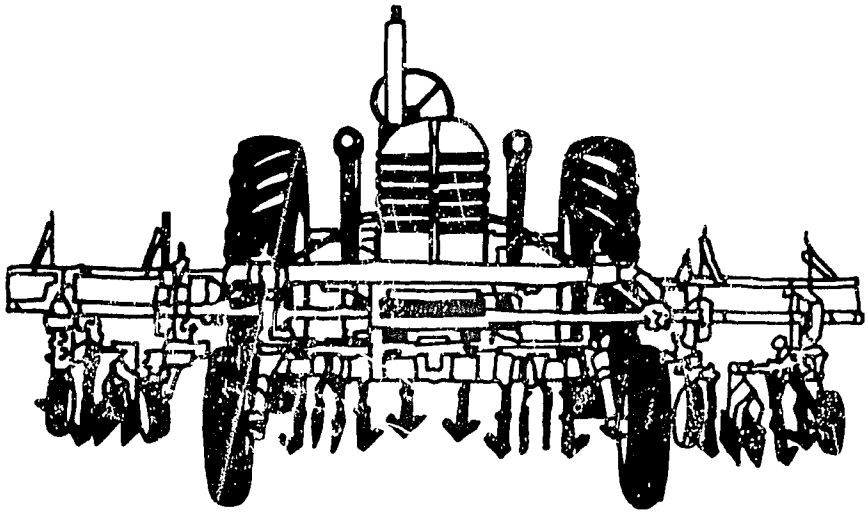
Mr. Tolson received his B.S. from North Carolina State University where he served as the student body president in 1961-1962. After serving as an officer in the United States Army, he jointed the Du Pont Company in 1965 as an advertising assistant. In 1970, he became a sales representative, a product manager in 1971, marketing manager for agrichemical in Europe and Africa in 1975, and in 1977 was named general marketing manager of the Agrichemical Marketing Division. In 1981 Mr. Tolson was appointed Director of Agrichemicals Marketing Division, Biochemical Department-Worldwide. In this position, he coordinates development and worldwide marketing for the entire line of Du Point agrichemical products.

Vega, Marcos R.

Dr. Vega attended the University of the Philippines (B.S.A.), Cornell University (M.S.) and North Carolina State University (Ph.D). He served as the Director of Training in which he had the administrative responsibility for the International Rice Research Institute's training program. This program covers both degree and nondegree training for participants coming mainly from rice-growing countries. In 1977, Dr. Vega was appointed Deputy Director General and has overall responsibility for IRRI's outreach programs. This responsibility entails travel to cooperating countries for discussion with national agricultural research scientists/ administrators on collaborative research plans and implementation. Dr. Vega is also active in scientific societies including the Weed Science Society of the Philippines, Asian-Pacific Weed Science Society and International Weed Science Society.

Vernon, Richard

Mr. Vernon received a B.S. from the University of Durham, a Diploma in Tropical Agriculture from the University of the West Indies, and a Post Graduate Certificate in Education from the University of London. During the past 15 years, he has gain considerable experience in tropical agriculture, mainly in Africa, agronomic research and extension, with an emphasis on weed management. Mr. Vernon temporarily served as the Principle Research Officer and as the Chief Agricultural Research Officer for Zambia. He later served as Leader of the Weed Control Research Extension Team for the Zambian Department of Agriculture and presently is an independent consultant in tropical agriculture specializing in weed management. Mr. Vernon is active in professional societies and is a member of the Tropical Agriculture Association (London) and Institute of Biology (London).



APPENDIXES

International Agencies in Technical and Advisory Support of International and Regional Organizations

CAB — Commonwealth Agricultural Bureaux
Farnham House
Farnham Royal
Slough SL2 3BN
U.K.

CGIAR — Consultative Group for International Agricultural Research
c/o World Bank
1818 H St NW
Washington, DC 20433
USA

FAO — Food and Agricultural Organization
Via delle Terme di Caracalla
00100 Rome
Italy

Some Government Agencies for Technical Training

ODA — Overseas Development Administration
Eland House
Stag Place
London SW1E 5DH
U.K.

BC — British Council
10 Spring Gardens
London SW1A 2BN
U.K.

TETOC — Technical Education and Training Organization for Overseas Countries
Dacre House
17-19 Dacre St
London SW1H ODJ
U.K.

GTZ — Deutschen Gesellschaft Fur Technische Zusammenarbeit (GTZ) G M B H
Postfach 5180
6236 Eschborn 1
West Germany

ORSTOM Office de la Recherche Agronomique
24 rue Bayard ORSTOM
75008 Paris
France

GERDAT Groupement d'Etudes et de Recherches pour le Developpment de l'Agronomie Tropicale
42 rue Scheffer
75016 Paris
France

International Agricultural Research Centers Under the Umbrella of CGIAR

CIAT International Center for Tropical Agriculture
Apartado Aero 6713
Cali
Colombia

CIMMYT International Maize and Wheat Improvement Center
Apartado Postal 6-641
Mexico 6, D.F.,
Mexico

CIP International Potato Center
Apartado 5969
Lima
Peru

IBPGR International Board for Plant Genetic Resources
c/o FAO
Via delle Terme di Caracalla
00100 Rome
Italy

ICARDA International Center for Agricultural Research in Dry Areas
PO Box 5466
Aleppo
Syria

ICRISAT International Crops Research Institute for the Semi-Arid Tropics
Patancheru P.O.
Andra Pradesh 502 324
India

IFPRI International Food Policy Research Institute
1776 Massachusetts Ave. NW
Washington, DC 20036
USA

IITA International Institute of Tropical Agriculture
PMB 5320
Ibadan
Nigeria

ILCA International Livestock Center for Africa
P O B 5689
Addis Ababa
Ethiopia

ILRAD International Laboratory for Research on Animal Diseases
PO Box 47543
Nairobi
Kenya

IRRI International Rice Research Institute
PO Box 933
Manila
Philippines

ISNAR International Service for National Agricultural Research
PO Box 93375-2509 AJ
The Hague
The Netherlands

WARDA West African Rice Development Association
PO Box 1019
Monrovia
Liberia

International Organizations

IDA International Development Association
1818 H St NW
Washington, DC 20433
USA

ISTA International Seed Testing Association
Reckenholz
P O B 412
CH-8046 Zurich
Switzerland

IAMFE International Association for the Mechanization of Field Experiments
LTI, 1432 Aas-NLH
Norway

IAALD International Association of Agricultural Libraries and Documentalists
Wageningen
The Netherlands

UNESCO United Nations Educational, Scientific and Cultural Organization
UNESCO House
19 Ave. Kleber
Paris 16e
France

IPPC International Plant Protection Center
Oregon State University
Corvallis, OR 97331
USA

IDRC International Development Research Council
Box 8500
Ottawa, Ont. K1G 4H9
Canada

IADS International Agricultural Development Service
Rosslyn Plaza
1611 N Kent St
Arlington, VA 22209
USA

ILRI International Institute for Land Reclamation and Improvement
PO Box 45
6700 AA Wageningen
The Netherlands

ICRAF International Council for Research in Agroforestry
PO Box 30677
Nairobi
Kenya

UNDP United Nations Development Program
1 United Nations Plaza
New York, NY 10017
USA

ISSS International Society of Soil Science
c/o FAO
Via delle Terme di Caracalla
00100 Rome
Italy

IAAE International Association of Agricultural Economists
Dartington House
Little Clarendon St
Oxford OX1 2HP
U.K.

IFDC International Fertilizer Development Center
502 First Federal Building
Florence, AL 35630
USA

Some Regional Centers and Organizations

AARD Agency for Agricultural Research and Development
Jalan Ragunan, 29 Pasar Minggu
Jakarta Selatan
Indonesia

AVRDC	Asian Vegetable Research and Development Center Shanhua Taiwan Republic of China
ASAIHL	Association of S E Asian Institutes in Higher Learning Secretariat Ratasastra Building Chulangkorn University Bangkok 5 Thailand
AIT	Asian Institute of Technology P O B 2754 Bangkok Thailand
BIOTROP	Seameo Regional Center for Tropical Biology PO Box 17 Bogor Indonesia
SEAMEO	South East Asian Ministers of Education Organization c/o SEAMES Darakarn Building 920 Sukhumvit Rd Bangkok 10110 Thailand
SEARCA	South East Asia Regional Center for Graduate Study and Research in Agriculture Los Banos Philippines
ASEAN	Association of S E Asian Nations ASEAN Secretariat Jalan Sisingamangaraja P O B 2072 Jakarta Indonesia
E-W Center	East-West Resources Institute E W Center Honolulu, HI USA
CATIE	Center for Tropical Agriculture Research and Training Turrialba 7170 Costa Rica
CARDI	Caribbean Agricultural Research and Development Institute University of the West Indies Campus St. Augustine Trinidad and Tobago

ESCAP	Economic and Social Commission for Asia and the Pacific United Nations Building Pajadamnern Ave. Bangkok 2 Thailand
a)	Regional Co-Ordinating Center for Research and Development of Coarse Grains, Pulses, Roots and Tuber Crops c/o ESCAP Agricultural Division (as above)
b)	Regional Network for Agricultural Machinery c/o UNDP PO Box 7285 ADC Manila Philippines
IICA	Inter-American Institute for Cooperation on Agriculture 1889 F St, NW, Suite 840 Washington, DC 20006 USA
AASA	Association for the Advancement of Science in Africa P O B 30087 Addis Ababa Ethiopia
STRC	Scientific Technical and Research Commission Nigerian Ports Authority Building PMB 2359 Marina Lagos Nigeria
BIS	Inter-African Bureaux for Soils BP 1352 Bangui Central African Republic
EAAFRO	East African Agriculture and Forestry Research Organization PO Box 30148 Nairobi Kenya
AAU	Association of Arab Universities Scientific Computation Center Tharwat St PO Giza Egypt
AOAD	Arab Organization for Agricultural Development P O B 474 Khartoum Sudan (Part of the Arab League)

RCD	Regional Cooperation for Development 5 Los Angeles Ave. Blvd Keshawarz P O B 3273 Teheran Iran (Agricultural Committee 1978)
CEEMAT/ GERDAT	Center d'Etudes e' d'Experimentation du Machinisme Agricole Tropical Parc de Tourvoie 92160 Antony France
IFARC/ GERDAT	Institut pour la Formation Agronomique et Rurale en Regions Chaudes BP 5035 34032 Montpellier Cedex France
IFCC/ GERDAT	Institut Francais du Cafe, du Cacao et autres Plantes Stimulantes 34 rue des Renaudes 75017 Paris France
IRHO/ GERDAT	Institut de Recherches pour Huiles de Palme et Oleagineux 11 Square Petrarque 75016 Paris France
IRAT/ GERDAT	Institute de Recherches Agronomiques Tropicals et des Cultures Vivrieres 110, rue del'Universite 75007 Paris France
IRFA/ GERDAT	Institut de Recherches sur les Fruits et Agrumes 6 rue du General Clergerie 75116 Paris France
IRCT/ GERDAT	Institut de Recherches du Coton et des Textiles Exotiques 34 rue des Renaudes 75017 Paris France
IRCA/ GERDAT	Institute de Recherches sur le Caoutchoul 42 rue Scheffer 75017 Paris France

COMECON International System of Scientific and Technological Information in Agriculture and Forestry
Council for Mutual Economic Aid
c/o Ministry of Foreign Affairs
Moscow
USSR

ICAR Indian Council for Agricultural Research
New Delhi
India

CIE Commonwealth Institute of Entomology
(HQ, Publications Office and Library)
56 Queens Gate
London SW7 5JR
U.K.

CMI Commonwealth Mycological Institute
Ferry Lane
Kew
Surrey
U.K.

CIBC Commonwealth Institute of Biological Control
Imperial College
Silwood Park
Ascot
Berks SL5 7PY
U.K.

CDC Commonwealth Development Corporation
33 Hill St
London W1A 3AR
U.K.

Some National Centers in Developed Countries

Institut fur Phytomeuizin, Universitat Hohenheim
Postfach 106
700 Stuttgart
West Germany

Tropeninstitute
Justus Liebig - Universitat
Griessen
G D R

Biologische Bundesanstalt fur Land-und Forstwirtschaft
33 Braunschweig
Messeweg 11/12
West Germany

National Institute of Agricultural Science
Konosu
Japan

Royal Tropical Institute
Mauritskade 63
1092 AD Amsterdam
The Netherlands

Agricultural University
Landbouwhogeschool
PB 9101
67 HB Wageningen
The Netherlands

Institute for Soil Fertility
PO Box 30003
9750 RS Haren (Gr)
The Netherlands

Department of Crop Husbandary and Plant Breeding
Royal Veterinary and Agricultural University
Thorvaldsensvej 40
DK-1871 Copenhagen
Denmark

Research Information Center
College of Agriculture
S-750 07 Uppsala 7
Sweden

Agricultural Research Council, Weed Research Organization
Begbroke Hill
Yarnton
Oxford OX5 1PF
U.K.

National Institute of Agricultural Engineering
Wrest Park, Silsoe
Bedfordshire MK45 4HS
U.K.

Overseas Spraying Machinery Center
Imperial College
Silwood Park
Ascot
Berks SL5 7PY
U.K.

International Center for the Application of Pesticides (ICAP)
Department of Bio-Aeronautics
Cranfield Institute of Technology
Cranfield
Bedford MK43 OAL
U.K.

Tropical Development and Research Institute
College House
Wrights Lane
London W8 5SJ
U.K.

International Tree Crops Institute
Convent Lane
Bocking
Braintree
Essex
U.K.

Intermediate Technology Development Group
Applied Research Section
Shinfield Road
Reading RG2 9BE
U.K.

United States Department of Agriculture
Agricultural Research Service
NPS 351 Administration Building
Washington, DC 20250
USA

United States Department of Agriculture
Agricultural Research Service
Beltsville, MD 20705
USA

United States Department of Agriculture
Agricultural Research Service
Southern Weed Science Laboratory
Box 225
Stoneville, MS 38776
USA

Regional Weed Science Societies

Europe

European Weed Science Society (EWRS)
Secretary: Dr. T. Eggers
Biologische Bundesanstalt
Messeweg 11/12
D-3300 Braunschweig
Federal Republic of Germany

North America

Weed Science Society of America (WSSA)
Secretary: Dr. O.C. Burnside
Agronomy Department
University of Nebraska
Lincoln, NE 68583
USA

Latin America

Associacion Latinoamericana de Malezas (ALAM)
President: Mr. Also Alves
EMBRAPA
Av. Francisco Glicerio, 957, 80 And.
13100 Campinas, SP
Brazil

Asian Pacific Region (including Australia, New Zealand, India, China, and Japan

Asian Pacific Weed Science Society (APWSS)
Secretary: Dr. R.K. Nishimoto
Department of Horticulture, Room 102
University of Hawaii
2190 Maile Way
Honolulu, HI 96822
USA

Africa

East Africa: Weed Science Society for East Africa (WSSEA)
Secretary: Dr. R.W. Michieka
Univ. of Nairobi
Dept. of Crop Sci.
PO Box 30197
Nairobi
Kenya

West Africa: West African Weed Science Society (WAWSS)
Secretary: Dr. G.C. Orkwor
National Root Crops Research Institute
Umudike, PMB 1006
Umudahia
Nigeria

South Africa: Southern African Weed Science Society
Secretary: Mr. J.J. Wells
PO Box 27552
Sunnyside
Pretoria 0132
South Africa

Eastern Bloc Countries (Including USSR)

COMECON Chemical Weed Control Conference
Contact: Prof. Melnikov
Vsesoyuznyi n-i
Institut Khimicheskikh Sredstv
Zashchity Rastenii
Moscow Zh 88
USSR

Proceedings of National and International Conferences and Symposia

National

United Kingdom; British Crop Protection Conference (Weeds) - formerly known as British Weed Control Conference (biennial)

USA and Canada; Weed Science Society of America (annually)
The North-eastern Weed Science Society (annually)
The North Central Weed Control Conference (annually)
The Western Society of Weed Science Conference (annually)
The Southern Weed Society Science Meeting (annually)
The Californian Weed Conference (annually)
The Proceedings of the Washington State Weed Conference (annually)
Canada Weed Committee - Eastern Section (annually)
Canada Weed Committee - Western Section (annually)

Germany; Arbeithesprechung uber Fragen der Unkrautbiologie und Bekampfung (Hohenheim) (biennial)

France; Comite Francais de Lutte contre les Mauvaises Herbes (COLUMA) (biennial)

Belgium; International Symposium over Fytofarmacie en Fytiatrie (annually)
International Meetings of Selective Weed Control in Beet Crops (every five years)

Scandinavia; Swedish Weed Conference (annually)
Scandinavian Pesticide Conference, Denmark, Finland, Norway and Sweden (annually)

Yugoslavia; Yugoslav Weed Control Conference (biennial)

Eastern Bloc Countries; COMECON Chemical Weed Control Conference
Also COMECON International Symposia

Australia; Victoria Weed Conference
Conference of the Weed Society of New South Wales (annually)
Australian Weed Conference (irregular)

New Zealand; Weed and Pest Control Conference (annually)

Asia; Asian-Pacific Weed Science Society Conference (biennial)

Other National Weed Societies publishing proceedings at irregular intervals;

Israel	Argentina	Nigeria
India	Brazil	Ghana
Portugal	Colombia	East Africa

International:

International Weed Science Society (no conferences yet)
International Congresses of Plant Protection (every four years)
International Symposia on the Biological Control of Weeds (irregular)
European Weed Research Society (formerly Council)
International Symposium on Parasitic Weeds (irregular)
International Conference on Mechanization of Field Experiments (every four years)
International Symposium on Aquatic Weeds (irregular)

Additional Sources of Information

International Libraries: AGLINET (Worldwide) Agricultural Libraries Network

International Center of AGLINET; David Lubin Memorial Library
FAO, Rome

Regional Centers;

a. United Kingdom and Ireland; Ministry of Agriculture
Fisheries and Food (MAFF) Library
London, U.K.

b. North America; National Agricultural Library
Beltsville, MD USA

c. Africa (West); International Institute of Tropical Agriculture
Ibadan, Nigeria

d. Latin America; Centro Internacional de Agricultura Tropical
Cali, Colombia

e. Germany (Federal Republic); Zentralbibliothek fur
Landbouwissenschaften (Bonn)

f. No geographic limitation on service;

International Rice Research Institute (IRRI)
Library Documentation Center
Manila, Philippines

g. Latin America; Centro Interamericano de Documentacion
e Informacion Agricola (CIDIA)
Turrialba, Costa Rica

h. Indonesia; Lembaga Perpustakaan Biologie dan Pertanian
'Biblioteca Bogoriensis'
Bogor, Indonesia

Additional member libraries;

Wageningen; Central Library of the Landbouwkhgeschool
South East Asia; Agriculture Information Bank for Asia
Laguna, Philippines

Herbaria:

There are too many Herbaria to list, but the following reference book lists all reliable herbaria around the world:

Holmgren, P.K., and Keuken, W. 1974. (Compilers)
Index Herbariorum. Part I.
The herbaria of the world. 6th edition
IAPT International Bureau for Plant Taxonomy and Nomenclature.
397 pages.

Publishers: Oosthoek, Scheltema and Holkema
Emmataan 27, Utrecht
The Netherlands

Center for Agricultural Publishing and Documentation
Wageningen
The Netherlands

International Association for the Development of Documentation Libraries and Archieves in Africa
B.P. 375
Dakar
Senegal

International System of Scientific and Technical Information in Agriculture and Forestry
Slezsko 7
Prague 2
Czechoslovakia

International Association for Plant Taxonomy
Bureau for Plant Taxonomy and Nomenclature
Room 1904
Tweede Transitorium
Uithof
3584 CS Utrecht
Netherlands

Computer Data Bases Covering Information on Weeds and Weed Control;

CAB - Abstracts Commonwealth Agricultural Bureaux, United Kingdom.

AGRICOLA - Agricultural Online Access, United States National Agricultural Library.

AGRIS - Agricultural Information System, FAO, Rome, Italy.

BIOSIS - Previews Biological Abstracts and Bio-Research Index, USA.

CA - Searches Chemical Abstracts, USA.

CHEMNAME CA- Chemical Name Dictionary (Complimentary file), USA.

NTIS - National Technical Information Service, USA.

Selected Publications Covering Weed Science (asterisk indicates free material)

AGRICULTURAL AND BIOLOGICAL CHEMISTRY
Japan Publications Ltd.
PO Box 5030
Tokyo International
Tokyo
Japan

AGRONOMY JOURNAL
American Society of Agronomy
677 South Segoe Road
Madison, WI 53711
USA

ANNALES AGRICULTURAE FENNIAE, and
ANNALES BOTANICI FENNICI
Akateeminen Kirjakauppa
Lehtiosasto
Postilokero 128
SF-0010 Helsinki 10
Finland

ANNALS OF APPLIED BIOLOGY
Biochemical Society (Pubs)
PO Box 32
Commerce Way
Whitehall Industrial Estate
Colchester
Essex
U.K.

ARCHIVES OF ENVIRONMENTAL CONTAMINATION & TOXICOLOGY
Springer-Verlag
Heidelberger Platz 3
D-1 Berlin 33
West Germany

AUSTRALIAN WEEDS
Inkata Press Property Ltd.
4 Longbourne Ave.
North Clayton, Vic. 3168
Australia

CANADIAN JOURNAL OF BOTANY
National Research Council of Canada
Sussex Street
Ottawa, Ont. K1A OR6
Canada

CANADIAN JOURNAL OF PLANT SCIENCE
Agricultural Institute of Canada
151 Slater Street, Suite 907
Ottawa, Ont. K1P 5B4
Canada

CROP SCIENCE
Crop Science Society of America
677 South Segoe Road
Madison, WI 53711
USA

DEFENSE DES VEGETAUX
149 Rue de Bercy
75595 Paris Cedex 12
France

ECOLOGY
Duke University Press
College Station Box 6697
Durham, NC 27708
USA

Business Publishers Inc.
951 Pershing Drive
Silver Spring
Madison, WI 20910
USA

ENVIRONMENTAL SCIENCE & TECHNOLOGY
American Chemical Society
PO Box 3337
Columbus, OH 43210
USA

EXPERIMENTAL HORTICULTURE TECHNOLOGY
PO Box 569
London SE1 9NH
U.K.

GEWASPRODUKSIE
South African Society of Crop Production
PO Box 1821
Pretoria
South Africa

GESUNDE PFLANZEN
Verlag Kommentator
Postfach 970148
6000 Frankfurt am Main 97
West Germany

INDIAN JOURNAL OF WEED SCIENCE
Indian Society of Weed Science
Department of Agronomy
College of Agriculture
Apau. Rajendranagar
Hyderabad-500 030 (AP)
India

*INFOLETTER
International Plant Protection Center
Oregon State University
Corvallis, OR 97331
USA

*INTERNATIONAL AGRICULTURAL DEVELOPMENT
Pharos Publishing Services Ltd.
5-11 Lavington Street
London SE1 0NZ
U.K.

INTERNATIONAL PEST CONTROL
McDonald Publications (of London) Ltd.
268 High Street
Uxbridge, Middlesex UB8 1UA
U.K.

IWSS NEWSLETTER
International Weed Science Society Secretariat
c/o IPPC
Oregon State University
Corvallis OR 97331
USA

JAPAN PESTICIDE INFORMATION
Society of Agricultural Chemical Industry (Japan)
Nihonbashi Club Building, 1-8-25
Nihonbashi-Muromachi, Chuo-ku
Tokyo, 103
Japan

JOURNAL OF AGRICULTURAL & FOOD CHEMISTRY
American Chemical Society
PO Box 3337
Columbus, OH 43210
USA

JOURNAL OF AGRICULTURAL SCIENCE
Cambridge University Press
The Edinburgh Building
Shaftesbury Road
Cambridge CB2 2RU
U.K.

JOURNAL OF AQUATIC PLANT MANAGEMENT
The Aquatic Plant Management Society Inc.
PO Box 16
Vicksburg, MS 39180
USA

JOURNAL OF THE ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS
1111 North 19th Street, Suite 210
Arlington, VA 22209
USA

JOURNAL OF THE BRITISH GRASSLAND SOCIETY
Blackwell Scientific Publications
Osney Mead
Oxford, OX2 OEL
U.K.

JOURNAL OF EXPERIMENTAL BOTANY
Oxford University Press
Journals Department
Walton Street
Oxford, OX2 6DP
U.K.

JOURNAL OF PESTICIDE SCIENCE
Japan Publications Ltd.
PO Box 5030
Tokyo International
Tokyo
Japan

JOURNAL OF RANGE MANAGEMENT
Society of Range Management
2760 West 5th Ave.
Denver, CO 80204
USA

JOURNAL OF THE SCIENCE OF FOOD & AGRICULTURE
Blackwell Scientific Publications
Osney Mead
Oxford OX2 OEL
U.K.

JOURNAL OF SOIL SCIENCE
Blackwell Scientific Publications
Osney Mead
Oxford OX2 OEL
U.K.

MALEZAS
Revista de la Asociacion Argentina para el control de Malezas
ASAM
Av. Corrientes 123. Of. 607
Buenos Aires
Republic of Argentina

NACHRICHTENBLATT DES DEUTSCHEN PFLANZENSCHUTZDIENSTES
Verlag Eugen Ulmer
Postfach 700561
7 Stuttgart 1
West Germany

NACHRICHTENBLATT FUR DEN PFLANZENSCHUTZ IN DER DDR
Deutscher Buch Export Und Import GWBH
Postfach 160
DDR 701 Leipzig
West Germany

OUTLOOK ON AGRICULTURE
Pergamon Press
Headington Hill Hall
Oxford OX3 OBW
U.K.

PESTICIDE BIOCHEMISTRY & PHYSIOLOGY
Academic Press Inc. (London) Ltd.
24-28 Oval Road
London NW1 7DX
U.K.

PESTICIDE SCIENCE
Blackwell Scientific Publications
Osney Mead
Oxford OX2 OEL
U.K.

THE PHILIPPINE WEED SCIENCE BULLETIN
Weed Science Society of the Philippines Inc.
Bio Science Building C-222
U.P. at Los Banos
College, Laguna 3720
Philippines

PHYTOMA
26 Rue Danielle Casanova
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