INTERNATIONAL AGRICULTURAL RESEARCH CENTERS:

ACHIEVEMENTS AND POTENTIAL

Part III

A Study
Directed by Jock R. Anderson

Draft of August 31, 1985

Part III REALIZED CONTRIBUTIONS OF THE PARTNERSHIP

Overview

Contributions that can be measured in concrete terms are clearly at the heart of any study of the impact of technological innovations arising from research. Reflecting the importance of plant breeding in CGIAR institutions, the first contributions addressed in this Part are those associated with germplasm. While the centers have been demonstrably important in the development of modern varieties, they are by no means the only actors in the scene. There are many research institutions in both the industrial and the developing countries that have been involved in the development of improved varieties and other related innovations. Indeed, the centers work closely with national agricultural research systems to improve their mandate crops.

Aspects of the story of modern varieties, especially of rice and wheat, have been told often and from many perspectives. The first chapter of this Part, however, deals more broadly with all the significant plant improvement programs at centers. So far as possible the spread of modern varieties is documented (chapter 6) and associated with the consequential changes in productivity and output. In the later chapters (beginning in chapter 7) the consequences of technological innovations other than modern varieties are addressed.

The complex issues of the distribution of benefits of technological innovations are addressed in chapter 8. These distributional questions cover the earnings of labor, land and capital and the geographic, social, economic and nutritional dimensions of the distribution that have attracted the

attention of critics of agricultural innovations. Much attention has been addressed to the production side of agriculture. There is a need for more concern for the consumer beneficiaries of changing agricultural productivity. Increasing numbers of consumers in the lower income areas of the world are clustered in large urban aggregates, so the provision of food to these dense populations which have no direct access to agricultural production demands serious attention.

Some of the other important but diverse products of the centers are also reviewed in chapters 9, 10, and 11 even though some involve dimensions that are difficult to quantify. The first is in the broad area of enhancement of human capital. The centers are all engaged in training programs of some sort although not all identify their activities that raise human capital as training per se. However they may be identified, the number of people who have received some assistance in their professional development now runs to more than 17,000; over 90 percent are men. They are nearly all working in partner countries, most of them in the research centers from whence they departed for their training. This topic has been the subject of an intensive investigation by consultants to the TAC in a study parallel to the present one, and their main findings are drawn together in chapter 9.

The final two "products" reviewed in this Part concern institutional changes discussed in chapter 10 and, in chapter 11, policy matters. Among institutional arrangements, the key issue to consider is the capacity of national programs to engage in agricultural research and to deliver the results to the target population. There are almost as many variations of institutional structure and organization as there are countries, and there is much to learn from comparative analysis of their experiences. Indeed, ISNAR

is addressed to such learning, and to extension of things that are found to work.

The final topic considered in this Part concerns research on policy for the agricultural and food sectors. Of course, IFPRI has this as its mandate, but all the other centers are concerned to some extent with policy matters, despite their restricted commodity foci and their heavy emphases on long-term biological research.

6 PLANT MATERIALS

6 PLANT MATERIALS

6.1 Introduction

The variety-related accomplishments of the collaborative research between the CGIAR centers and agricultural researchers in developing countries are addressed in this chapter. The extent of varieties released, their spread, their breeding, their effect on food production and its stability, and their contribution to increased agricultural productivity are examined. Matters relating to germplasm per se are taken up in chapter 12.

6.2 Collaborative Research in Varietal Development

Several joint products can be identified as resulting from the collaborative work of the international centers and the national programs on varietal development: (a) varieties obtained from one country and supplied as promising materials by an international center to researchers in another country, (b) varieties developed and made available by centers, (c) varieties selected by national programs from crosses made by and selected as promising materials by an international center, (d) varieties selected by national programs from crosses made at an international center and supplied to a country as early generation segregating material, (e) varieties resulting from crosses made by national scientists from parent material supplied (perhaps in part) by an international center, with selections made by national scientists, and (f) varieties resulting from more complex cooperation such as crosses made by either international centers or national researchers with evaluation and selection made by both in alternating generations from materials shipped back and forth between a center and a national program. While all these and

possibly some other kinds of genetic material may be related to centers, varieties developed independently by national programs from crosses with one or more center parents are not center-related in the sense used here.

It is the intention in this study, to use "center-related" or "center-derived" to designate varieties developed by processes (a) through (d), but full information about all varieties is not always available. Furthermore, because of the many possible ways in which germplasm from a center and a national program may be combined, evaluated and selected, it is impossible to quantify the contributions of national programs as distinct from centers. For example, the Brazilian rice variety CNA 7 was introduced from India as IET 2881 where it had been produced from a cross of T 141 with IR 665-1-175-3. A Brazilian maize synthetic, BR 105, was developed in the early 1980s by EMBRAPA from germplasm originating in the Caribbean and selected in Thailand by CIMMYT. Increasingly, national programs are taking over more of the collaborative process of plant improvement. Every effort has been made in what follows to designate as "center-related" varieties only those in which centers' had a direct hand, i.e., those described in (a) through (d).

6.2.1 Naming varieties

According to a dictionary definition, a crop variety is a recognized, genetically homogeneous group of plants of less than species rank. Farmers and plant breeders (sometimes one and the same) use "variety" to refer to a group of plants that are recognized as having a set of inherited characteristics differentiating them from other sets of the same crop and which have been given a name and are approved for cultivation, either by custom or by some duly constituted authority.

A land race is a set of plants of a crop of a less homogeneous nature than a variety, but still similar, which has been recognized by custom or tradition. Land races are sometimes highly heterogeneous and are normally found in agricultural systems isolated from interchange with other systems. Farmers and lay persons sometimes call these varieties, while plant breeders and geneticists usually prefer the term land race or "primitive form".

Lines are small sets of plants in the intermediate stages of varietal development. Because of the nature of plant breeding, lines are less homogenous than varieties, and therefore provide scope for selecting individual plants with performance superior to that of other individuals in the same line.

Cultivar is used as a more specific term than variety or land race, to identify a homogeneous set of plants cultivated as a crop. The word also has a more technical meaning related to official description and registration in some countries.

A hybrid is the result of a cross between two different cultivars. In common use, hybrid denotes a special type of variety produced through crossing inbred lines; seeds of a hybrid must be produced each year by making the same crosses. Conventional varieties are produced by creating a hybrid and then selecting from successive generations until uniform offspring are produced. Varieties of cross-pollinating or out-breeding crops such as maize may consist of various kinds of population mixtures or composites of genotypes.

While varieties may acquire recognition through informal processes, in today's world, for all practical purposes, they must be named. The act of

naming indicates approval by the naming authority that the variety is suitable for cultivation under certain conditions. Depending on the availability of information and resources, and the extent of control by the authority, the specification of the conditions for which a variety is suitable may be rather general or quite specific.

Most countries grant the authority to name varieties to national variety registration boards (sometimes "seed boards") but, in some large countries, state or provincial seed boards may have the authority to name varieties. Seed boards usually require the individual or institution proposing cultivars for naming to provide evidence of performance and some minimal quantity of "breeder's seed" to permit evaluation of performance and to provide the basis for subsequent multiplication.

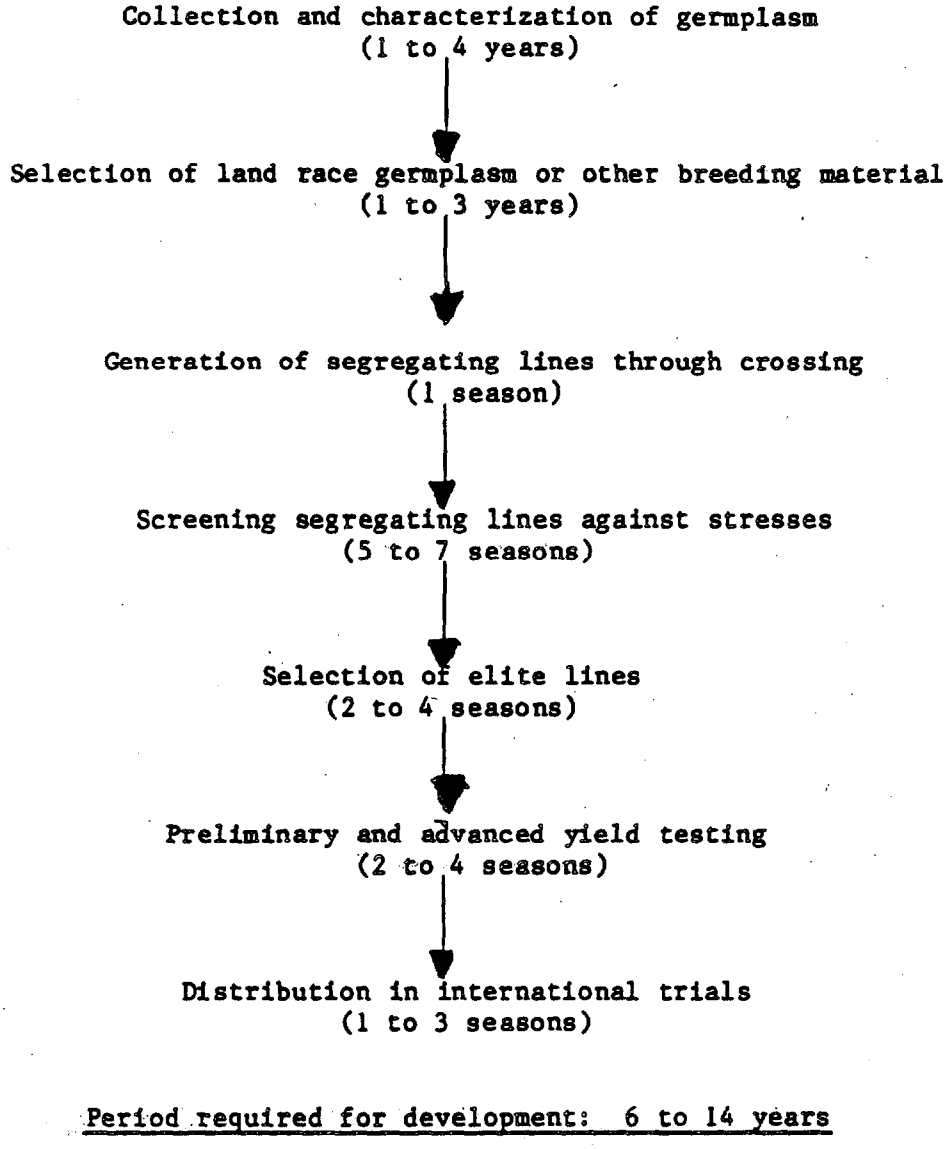
Most CGIAR centers do not name varieties although, for example, until 1975 IRRI did name varieties that were used within the Philippines and elsewhere. Seed boards in many countries use the designations of plant breeders as names for varieties where they are suitable, or choose some name that indicates the institution or organization responsible for developing the variety. For example, CSH-1 designates coordinated sorghum hybrid 1, the first hybrid sorghum developed by the All-India Coordinated Sorghum Improvement Programme. Similarly, many countries use an abbreviation of the center designation when they name center-related varieties while others choose unrelated names.

6.2.2 Time requirements for varietal development

Plant breeding is a time-consuming process (Figure 6.1). It starts with collection of existing varieties, breeders lines, mutant stocks and land

Figure 6.1

STAGES IN THE DEVELOPMENT OF CROP VARIETIES



Period required for development: 6 to 14 years

races; these are studied and examined for useful characteristics. Then pairs of cultivars are crossed to produce F_1 hybrids (the first generation). The F_1s are planted and harvested to give F_2 seed, which in turn is planted to give the F_3 generation, and so forth. Sometimes the F_1 is backcrossed to one of the parents or to another cultivar. Each time a new generation is grown, the plant breeder has an opportunity to observe the reaction of the crop to whatever set of circumstances exists or is created. If a particular generation is grown during a droughty season that kills most individual plants but through which some survive, the individual surviving plants have a greater degree of resistance to or tolerance of drought. These early generations "segregate" in their reaction to particular stresses because each individual plant has a different combination of genes. Subjecting the plants to the same stress for a number of generations ensures that only those resistant to that stress will survive.

Plants are purposively subjected to a series of stresses, i.e., "screened" against insects, plant diseases, acid or alkaline soil conditions, or other factors, in order to observe their reactions. Depending on the genetic dominance or recessiveness of a characteristic, resistant plants may be identified by screening over a number of generations (dominant), or in a single generation (recessive).

The process is time consuming because one season is required to grow each complete generation, and because screening for different characters is normally carried out sequentially, although seed lots can be divided and subjected to different stresses at the same time. In addition, most important plant characters are controlled by many genes. Thus, drought resistance is a complex characteristic to which many plant mechanisms such as leaf stoma

reactions, leaf wax composition, root density and root length, all contribute. After identifying several lines that each carry a gene for one desired characteristic, additional crossing and selection is required to combine the several desired genes into a variety that has the necessary characteristics.

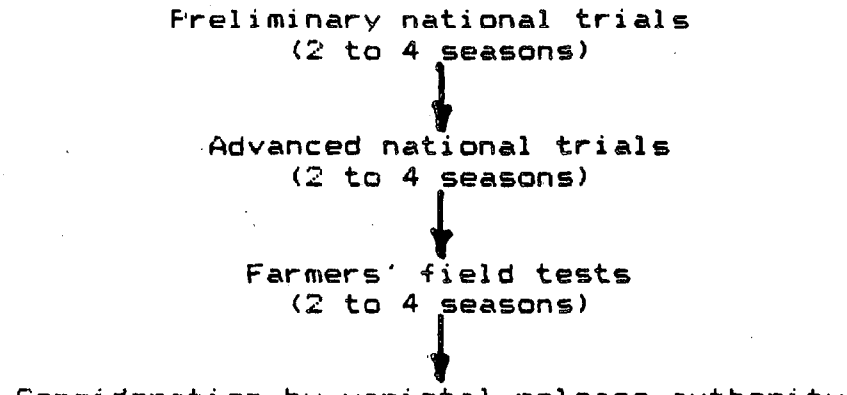
The breeding process can be speeded up somewhat by growing alternate generations of a normally rainfed crop with irrigation in the "off" season, in a greenhouse, or by rotating through different climatic areas. This also subjects the generations to different sets of growing conditions, which naturally affects the combination of genes in the resulting selections.

After five to seven generations of screening, the best remaining lines are selected as elite lines and subjected to preliminary yield testing, which requires a greater quantity of seed than for selection in the early generations. If a line is good enough it goes on to advanced yield testing, and then perhaps to an international or multilocational national yield trial. Advanced lines may be entered in "observational trials" in a number of locations so that plant breeders outside the originating station may observe performance under local conditions. By the time a variety is named, it has been evaluated for many characters by a number of plant breeders and others.

Additional time is required for national authorities to test and evaluate the suitability of received materials for their individual conditions (Figure 6.2). Normally they evaluate materials in a preliminary way (often as part of an international nursery). Promising materials go on to advanced trials and then to farmers' fields. The process may be cut short somewhat by evaluating earlier in farmers' fields, but only a relatively few lines can be evaluated in farmers' fields because farmers are naturally more interested in

Figure 6.2

STEPS IN TESTING VARIETIES BY NATIONAL PROGRAMS PRIOR TO RELEASE



Period required for testing and release: 3 to 6 years

growing crops and running their own informal trials of materials and practices than acting as de facto directors of experiment stations. Testing under farmers' conditions is more expensive for national authorities than on experiment stations because it involves additional travel and supervision costs. Three to six years usually elapse between first evaluation and release of a new variety.

A minimum of six years may be required between initiation of germplasm collection and identification of promising lines from it. Where highly seasonal rainfall or temperature regimes restrict evaluation to only one cycle each year the process may take up to 14 or even more years. Three to six years may be needed for evaluation in a country that carefully examines materials obtained from outside sources. Even where cultivars are simply collected and supplied to national researchers for evaluation and local testing, several years elapse between the beginning of a program and the naming of varieties by countries. The research that led to the release of CIMMYT wheats in the mid-1960s began 20 years earlier in Mexico and elsewhere. IRRI was fortunate that its cross of a semi-dwarf rice from Taiwan with a high quality tropical variety from Indonesia produced IR8 within five years, but such good luck is unusual. Researchers in Thailand started working with Rockefeller Foundation scientists to develop improved maize in 1959. The first variety was released in 1969 but it was not resistant to downy mildew. Not until 1975 was the first resistant variety released. Where a crop is not receiving much research attention, even direct transfers take time. Chile began research on chickpeas with materials imported from the U.S.A. in 1976; the first variety was launched in 1983.

Centers that began breeding programs in the late 1960s and early 1970s on field beans, cassava, cowpeas, chickpeas, tropical sorghum, pearl millet and tropical pastures had to begin by collecting germplasm and determining how the existing varieties could be improved. The base of knowledge and collected germplasm on which to build was small in these crops, so it is not surprising that the early products are just being named by countries in the early 1980s. Ten years after IRRI began, countries other than the Philippines had named 10 lines developed at IRRI as varieties. Fifteen years after CIAT began its bean program, 20 varieties had been named by country programs. Fifteen years after IITA began its cowpea research, 21 of its varieties had been named by country programs. Thus, it is clear that, by 1985, the CGIAR centers, including those that started later than CIMMYT and IRRI, are indeed seeing the fruits of their varietal development work accepted by developing countries and their farmers. Rates of farmer adoption are influenced by several biological attributes, including the different rates of potential multiplication associated with the various methods of propagation used for different crops.

Since the late 1970s, an ever growing number of lines of crops have been developed by the centers, distributed through international varietal testing programs for evaluation by national authorities, and named by national seed boards. An increasing number of national programs are obtaining segregating lines from centers and doing their own screening, selection and yield testing. Because the seed boards are independent and are located in countries throughout the world, it is impossible to have information about all the varieties named, but a summary of information about those known to have been named as of mid-1984 is presented in Table 6.1. Because the table shows numbers of varieties released by countries, and not number of germplasm lines, it reflects multiple counting of lines released by more than one country.

Table 6.1 Number of CGIAR center related varieties released by national authorities in developing countries through 1983[a]

Crop	Number of varieties named by countries in				
	Africa	Asia	Latin America	Middle East & North Africa	Total
Barley	0	2	0	8	10
Beans, field	4	2	90	0	96
Cassava	26	5	32	0	63
Chickpeas	0	1	0	2	3
Cowpeas	14	2	12	1	29
Maize	61	49	126	2	238
Pasture species	0	0	12	0	12
Pearl millet	5	3	0	0	8
Pigeonpea	5	2	0	0	7
Potatoes	31	16	12	2	61
Rice	31	140	129	2	302
Sorghum	8	18	5	0	31
Sweet potatoes	6	0	0	0	6
Triticale	2	2	7	0	11
Wheat, bread	40	44	114	66	264
Wheat, durum	5	3	13	20	41

82085

[a] Excludes varieties developed from crosses made by national programs from sources similar to those used by the centers.

It is evident from the table that research on the various mandate crops has reached different stages. Countries have evaluated and released large numbers of wheat and rice varieties. Their spread is discussed in section 6.3. A smaller number of maize, cassava, field bean, potato and cowpea varieties have been named, along with a few of chickpea, pearl millet, sorghum and some pasture species.

This is not to suggest a larger role for the centers than they have played. Many national research systems have developed and released improved varieties independently of the centers, in addition to those developed in cooperation with the centers. For example, there are 52 varieties in a list of improved rice varieties named by Indonesia; of these 18 are directly center-related and are counted in the listing of Table 6.1. A similar effort has been made to exclude varieties of other crops only distantly related to the centers.

6.2.3 Center-related maize varieties

Based on materials supplied from the centers, over 200 maize varieties have been developed and released by national authorities in 41 countries. Most of these were named by Latin American countries, but countries in Asia and Africa have named about 50 in each region. One particular group of lines called "Tuxpeno" has been of special value in obtaining disease resistance for lowland tropical areas; the discovery and incorporation of streak resistance into advanced maize lines by IITA has been important for maize production in African countries. It is estimated that the center-related varieties are being grown on over 6 million ha in developing countries, including Costa

Rica, Brazil, Ecuador,Mexico, Guatemala, Honduras, Ghana, Tanzania, Nigeria, China, India, Burma and Thailand.

Even though these releases have been made, the maize research of the centers has had less impact on production of foodgrain than has wheat or rice research, raising the question of why. At least four factors contribute. First, maize is grown under a great diversity of conditions in the developing world, and any individual variety is adapted to only a narrow range. Thus a great many individually adapted varieties must be developed, and these can only effectively be adapted by local researchers. This contrasts with irrigated wheat and lowland rice which are grown in fairly homogenous environments. Second, in the developing world, maize is grown in many countries, unlike rice which is concentrated in Asia, and wheat which is concentrated in the Indo-Gangetic plain, the Middle East and North Africa. Thus international maize researchers must forge a greater number of institutional links than must wheat or rice workers in order to reach the same proportion of national maize workers. Third, while it might appear that a large backlog of plant improvement existed for maize before the centers started, in fact, the prior research was addressed largely to yellow dent types, while people in developing countries who eat maize mainly use white flint types. Fourth, because the improved maize populations from CIMMYT and IITA have no universal physical characteristic such as semi-dwarf stature, their crosses with local varieties and their adoption by farmers is much less apparent than was true for semi-dwarf wheat and rice.

Despite these problems, there has been considerable use of center-related maizes both directly and in national breeding programs. Reflecting the widespread nature of maize production, national researchers in most of the

country case studies commented on the contribution of center-related maize germplasm.

Researchers in Brazil reported on 12 released maize varieties that had been selected from crosses made with germplasm from CIMMYT or from CIMMYT populations since the late 1970s (Homen de Melo 1985). About half of these contained Tuxpeno genes, and most were cited for their resistance to downy mildew, Helminthosporium or other diseases, as well as resistance to lodging. One was cited as drought resistant. Each was recommended for certain states or portions of states. Brazilian maize breeders have developed many more varieties unrelated or more remotely related to center-supplied germplasm.

Researchers in Guatemala have produced nine varieties and three hybrids from CIMMYT-supplied germplasm (Stewart 1985). Nine of these have been released since 1978. A high quality protein variety, Nutricta, has been released and is being grown on about 500 ha. National plant breeders have also selected varieties for the highlands where no imported materials seemed to work.

National scientists of Costa Rica estimate that 10 to 15 percent of the 1984 maize area was planted to TICO V-1 Mejardo and Diamantes 8034, two varieties developed by the Ministry of Agriculture from materials supplied by CIMMYT (Stewart 1985).

In the Sierra region of Ecuador, the activities of the Andean maize Improvement Agreement involving CIMMYT and several countries of the region have resulted in the identification, testing, release and adoption of varieties for farmers. Because they are developed locally, they are highly

adapted, and varieties have already been launched that have been adopted by farmers (Posada 1985).

Zimbabwe has an advanced maize breeding program of its own, which started in 1930 and, in 1949, released the first commercial hybrid maize produced outside the United States (Billing 1985a). A significant achievement of that program was the release of the widely grown 150-day hybrid SR52, based on two local parents. Subsequently, 130-day hybrids have been released. Some material from CIMMYT's high lysine program is being incorporated but the high lysine gene is associated with a soft kernel. Zimbabwe's researchers are backcrossing elite inbred lines with streak-virus resistant sources from IITA. Kenya, like Zimbabwe, grows hybrids extensively and is using center germplasm in the development of new parent lines.

Nigeria has made good use of two maize populations, TZB and TZPB, which were developed during the early days of the IITA program. TZB originated from African and Latin American sources with major contribution from Nigerian Composite B. TZPB is derived from Tuxpeno Planta Boja Cycle 7 from CIMMYT. The two populations were released from Nigeria's National Cereals Research Institute under the names FARZ 27 and FARZ 34. Both have good resistance to tropical rust and lowland blight. They are the most widely grown varieties in Nigeria with a total of 200,000 ha reportedly under these varieties in 1981, according to the National Accelerated Food Production Programme. It is estimated that the two varieties were grown on about 1 million ha in Nigeria in 1984 (Okoro and Onuoha 1985).

CIMMYT has been supplying Malawi with germplasm for 15 years (Billing 1984b). Its major thrust in the 1960s was on composite varieties. The first,

Chitadze Composite A (CCA) contained 80 percent local materials and 20 percent material imported from other African countries. The second, CCB contained about 60 percent CIMMYT materials but it was not sufficiently resistant to diseases. Currently breeders are working on a third, CCC, which has a higher percentage of CIMMYT material and gives about 10 percent higher yields under drier conditions. Another newly released variety, selected from Tuxpeno, has been under local development for 10 years and is somewhat more resistant to drought than CCC.

Tanzanian plant breeders have used germplasm from CIMMYT and IITA maize populations such as La Posta, Pool 16, TZSR-W and TZSR-Y to obtain streak virus resistant cultivars that have recently been released or are being released (Ndunguru 1984).

Researchers in Cameroon have tested over 100 composites of center maize and have released a number (Lyonga and Negwo 1985). TZB and TZPB, as in Nigeria, have proved to be attractive to farmers. These two varieties cover some 10-15,000 ha in the country. Several other varieties have also been recently released.

Thailand has been the center of an inter-Asian maize improvement program since 1959 when the Rockefeller Foundation stationed a field staff member there (Isarungkura 1985). Plant materials were imported from Guatemala, crossed and evaluated in Thailand and other S.E. Asian countries. In 1969, the first improved variety for Thailand was released from the program. The program cooperated closely with CIMMYT and countries of the region to develop downy mildew resistant (DMR) materials, and in 1975, DMR Suwan No. 1 was released. Subsequently, other DMR materials were released and, by 1984,

national authorities reported that virtually all the maize grown in Thailand (about 1.7 million ha) was derived from this program.

Indonesian farmers also derived some benefit from new CIMMYT-related maize varieties which, together with improved cultural practices, have helped to raise average yields from 1.1 t/ha in 1973 to 1.7 t/ha in 1983 (Nestel 1985). In the Philippines, the DMR varieties have been less successful and, in recent years, private companies have begun to develop high-yielding hybrids that are finding acceptance among some farmers producing maize for the feed market.

Maize is a minor crop in Burma, but it is suited for human food as well as animal feed. In 1978, the government undertook a maize production program with the assistance of UNDP/FAO. The project obtained germplasm from countries in S.E.Asia and from CIMMYT to test for local adaptability, drought tolerance and early maturity (Zin 1985). Six varieties have been released from the program and have been well adopted by farmers.

6.2.4 Cassava, beans, potatoes, millet, sorghum and cowpeas

Cassava. Twenty-six varieties of cassava related to IITA germplasm have been named and released by six African countries and over thirty varieties related to CIAT germplasm by ten Latin American and Asian countries. The spread of improved cassava has been slowed by the slow growth of demand for cassava in Latin America, but the demand is expanding more rapidly in most African countries.

IITA researchers have incorporated resistance to a number of cassava pests, including the green spider mite, cassava mosaic virus and cassava mealy

bug. All of the country case studies in Africa report these are actively being tested. Researchers in Nigeria and Cameroon collaborate with IITA by supplying materials for evaluation and conducting preliminary, advanced and uniform yield trials (Okoro and Onuoha 1985). A number of clones have been identified as superior to local ones in uniform yield trials. Kenya has just begun to test IITA materials (Ruigu 1985). Tanzania is testing IITA materials for tolerance to major pests (Ndunguru 1985).

Zimbabwe's research department had not devoted much emphasis to cassava in the past, since it was a minor food crop (Billing 1985a). Migrants from Malawi have increased the demand for cassava and the department has recently started agronomic trials on materials supplied to them by IITA. The University Crop Science Department has also started a cassava research program. The range of available materials has been adequate to enable the national system to forgo a breeding program.

Cassava is more important in Malawi. IITA has made a major effort to assist the country in establishing a research program (Billing 1985a). National researchers were trained and encouraged to evaluate local material before attempting incorporation of IITA material; the center assisted in devising a strategy to assist national research and extension workers to gain farmer adoption of the new varieties.

Field beans. Over 90 CIAT-related field bean varieties had been named by 18 Latin American countries by mid-1984 and five countries outside the region named CIAT-related beans. Many of these are Dorado beans, a group of new varieties that are resistant to the bean golden mosaic virus. In Guatemala, surveys by the Instituto Interamerican do Cooperacion para la Agricultura

(IICA) in 1982/83 indicated that 40 percent of the smaller-scale bean growers and 60 percent of the larger-scale growers had switched to the Dorado varieties (Viana and Pachico). In Costa Rica, it is estimated that 35 to 40 percent of bean area is planted to varieties developed in collaboration with CIAT (Ballestro 1985). In Cuba, since 1981, about half the bean area has been planted to ICA-Pijao, a variety introduced through CIAT. Over 10,000 ha are planted to the variety in the state farm sector while private sector plantings have averaged 5000 ha. A survey of farmers in the four Argentinian states that account for 95 percent of the black bean production of that country indicates that, in 1984, improved varieties were being grown on 65 percent of the area (Gargiulo 1985). In addition, Mexico, Cuba, Argentina, Haiti and the Dominican Republic are multiplying the Dorado bean seeds or had them growing on farmers' fields in 1984.

Farmers in Guatemala reported an average yield of 910 kg/ha with the new beans compared to 750 kg/ha with their traditional varieties. There was no difference in the use of other inputs between the two types. In the Costa Rican case study, farmers reported yields of 1050 kg/ha for the new variety Talamonca compared to 940 kg/ha for an earlier introduced variety, and 600-700 kg/ha for traditional local varieties. In Argentina, yields of the new beans averaged 1360 kg/ha, a 26 percent increase over local bean varieties. Apart from adopting the new variety, farmers do not appear to have changed their production practices, so the entire increase in output except for the cost of new seed is a net gain.

Even where CIAT varieties are not directly suitable for conditions of the country they can make a contribution to varietal advance. For example, in Chile, research on beans has benefited from the support of CIAT which has

supplied lines resistant to mosaic and root fungi since 1975. CIAT has also made specific crosses for the Chilean national program.

In Brazil, the contribution of CIAT bean varietal improvement work is just at the stage where it will begin to make an impact. Researchers identified seven varieties being released to farmers in 1983 or 1984 that they had developed by selecting or crossing center-derived materials, or varieties developed in other countries from center materials.

Potatoes. By 1984, 23 developing countries had released or named 61 potato varieties developed from germplasm provided by CIP. CIP obtained many of these from ongoing potato research programs in the industrial world through their contract research program. Other varieties were collected by CIP researchers from national programs in one location and provided to researchers elsewhere in the process of germplasm exchange. At the same time, improved potato lines developed by CIP breeders that combine resistance to the most important diseases are being evaluated by national researchers in 53 developing countries. Varieties resulting from these breeding efforts are expected to begin to be named in the next five years.

The strategy being followed by CIP to introduce improved germplasm is illustrated by the case of the central African highlands area where about one million small-scale farmers in Rwanda, Burundi, Zaire and Uganda grow about 120,000 ha of potatoes annually. The first step in the strategy was to select improved local varieties from farmers' fields for cleaning up and multiplication in seed units set up by the program. The second step was to introduce some improved varieties from other ecologies. The third step was to select

Feature: Dorado Bean Varieties: A Collaboration

Bean research specialists in Panama, Cuba, Haiti, Mexico, Guatemala, Honduras, El Salvador, Costa Rica and the Dominican Republic joined with CIAT during the late 1970s in a network to improve field bean production in Central America where beans supply over 15 percent of most people's protein. Each participating country within the network agreed to undertake specific responsibilities for an overall bean technology development program, with CIAT providing backup support to the joint enterprise.

Bean golden mosaic virus (BGMV) is one of the main constraints to Central American bean production, especially in the drier, lowland areas of Mexico, Central America and the Caribbean. Guatemala accepted responsibility for working toward virus-tolerant bean varieties within the network. CIAT helped with germplasm and some strategic research which included isolation of the BGMV at CIAT. After screening the germplasm bank under heavy natural pressure for promising material, CIAT researchers raised the pressure even further by surrounding the test lines with other crops that carried the virus and its vector. Crosses were made in 1975/76 at CIAT and the segregating lines were sent to Guatemala for selection under field conditions.

The selections looked excellent. One line, DOR 41, grown without chemical insecticide to protect it from the insect that transmits BGMV, yielded 1340 kg/ha while the susceptible commercial variety yielded 550 kg/ha. Basing their decision on such encouraging results, Guatemala research authorities decided to speed their testing, and released three promising lines

in 1979. The varieties quickly spread to farmers fields so that by 1982/83 they covered more than 40 percent of Guatemala's bean area.

Promising lines were sent to the other members of the network. Line DOR 60, which had been screened at the F_2, F_3 and F_4 generation level in Guatemala was taken to Mexico where it was tested by researchers in the national program and in one trial yielded 1270 kg/ha compared to 560 kg/ha for the traditional variety. It was released by Mexico in 1981 under the name Negro Huasteco 81.

Cuba selected several lines from the international nursery. The first to be released has spread to over 10,000 ha. Line DOR 15 was released under the name Tomeguin 1. Still another, DOR 41, is in the advanced testing program where it is being evaluated and adapted to local conditions. The Cuban researchers will pass the results back to the Guatemalan researchers who developed it.

The same line, DOR 41, caught the attention of Argentinian researchers through its performance in the international nursery. They saw it as a possible solution to a different disease, bean chloritic mosaic virus. They multiplied the seed and, by 1984, farmers were planting some 20,000 ha to it. Researchers in Haiti and the Dominican Republic have also selected DOR lines for their conditions and in 1984 were testing them on farmers' fields prior to seed multiplication and release.

varieties under local conditions from among tuber families supplied from CIP. Through this strategy, large amounts of improved materials are available to farmers. Since 1979, six new local varieties that were tested at several sites and on farms have been released. Rwanda will plant around 9000 out of 45,000 ha to these improved varieties in 1984, providing the seed requirement of 2 t/ha of seed potatoes from its own production. A further step has been to test consumer preferences in relation to the different characteristics required by different coding techniques and end uses and the comparative acceptability of varieties at various price levels. Recent consumer studies have drawn attention to variability in flavor and nutritional quality of the same varieties grown in different production zones.

Pearl millet. Pearl millet is an important food crop in relatively few countries. They tend to be those that have some of the harshest environments in the crop-growing world. It is usually grown by people who have few other sources of income. India, Pakistan, Zambia and Sudan have released six pearl millet varieties derived from ICRISAT materials. Another 15 are either in the advanced testing or pre-release stages. It is estimated that, in 1984, such pearl millet varieties released in India covered nearly 600,000 ha. Varietal development work is actively in progress in Niger, Burkina Faso, Nigeria and other areas in the semi-arid tropics.

Sorghum. Sorghum is another crop grown under harsh environmental conditions by many poor people. In 1980, Ethiopia released its first ICRISAT-derived sorghum variety and since then has released three others. Burma released ICRISAT-related varieties in 1981 and 1982, and by 1984 the national authorities estimated that 23,000 ha out of a total of 190,000 ha were planted to these new varieties. Burkina Faso also released several center-related

varieties in recent years. By 1984 it was estimated that 31 sorghum varieties derived from the ICRISAT program had been released. Kenya was yield testing 40 lines and was multiplying 4 varieties prior to their release. Many lines were being used in crossing programs in Mexico, Kenya, Malawi, Guatemala and other countries.

The national research program of Sudan and ICRISAT developed a promising hybrid sorghum in January 1983 in a UNDP-supported project. Twenty tons of seed of the new hybrid, Hageen Durra-I, were planted by farmers in 1984. Under farmers' rainfed conditions it gave an average yield of 810 kg/ha compared to the 270 kg/ha given by local varieties. During 1984 about 350 tons of seed were produced, enough to plant 125,000 ha, and 2000-4000 tons of seed are estimated to be needed for 1985. If available, that could cover 0.5 to 1.0 million ha.

Cowpeas. Fourteen countries had released 29 varieties of IITA-related cowpeas by 1984. Of these, 14 had been released in African countries. Thirteen varieties are known to have been released in 1981 and 1982. The first release was by Venezuela in 1979, followed by releases in Tanzania, Burkina Faso and Nicaragua in 1980.

Nigeria released two cowpea varieties derived from IITA materials in 1983: "Dan Knarda" and "Exorowo" from TVX 3236 and IT82E-60, respectively, which have found ready acceptance by many farmers. In just one development effort, these cowpeas were being produced as a sole crop by about 9000 farmers in the Kano Agricultural Development Project in 1984. They grew a total of about 4000 ha and made profits of about 2000 Nira per hectare. Another 2000 ha are being grown outside the project area (Okoro and Onuoha 1985).

Zimbabwe has evaluated a wide range of IITA cowpeas and selected promising varieties in experiment station tests during the 1981/82 season. They were subsequently field tested and grown at sites in communal farming areas under farmers' conditions, achieving yields of one t/ha under rainfall as low as 200 mm and appeared to be extremely promising to local researchers. Seeds are being multiplied. Researchers in Cameroon likewise report that several cowpea lines are being multiplied prior to their release to farmers.

More lines and varieties of these crops are known to be in the advanced stage of testing in many countries, but as in the case of breeding, the process of testing is time consuming and one that requires a certain amount of local competence and resources. Countries require up to eight years of testing at a number of locations before varieties can be released, although in some cases, where a country has faced urgent needs and varieties appeared to be unusually well suited, seeds directly imported from elsewhere have been released to farmers.

The process of screening requires competent investigators and the process of testing requires a national varietal testing organization or at least a well qualified extension system. Countries that do not have adequate personnel or adequate budgets for such activities cannot effectively carry them out. They can, of course, grow varieties developed in other countries or at the international centers but, because the particular combination of conditions and stresses that make a variety perform well in one location may be different from what is required in another location, relying on varieties developed elsewhere may not give well-adapted varieties. This need for local screening and testing prior to release of a variety is one of the advantages

that the countries hosting the international centers have -- multilocation testing of promising lines is done by the center as a part of its breeding program and so need not necessarily to be done by a national organization.

6.3 The Spread of New Wheat and Rice Varieties

To date, the bulk of the increased food production resulting from the joint research efforts of international and national researchers has been from wheat and rice. Nearly 50 percent of the wheat land and over 55 percent of the rice land in the developing countries was planted to semi-dwarf varieties in 1984. Most of these varieties are related to center-provided germplasm except for the rice in China, where semi-dwarf varieties were discovered independently. More recently China has been using IRRI varieties widely as parents for its hybrid rices. Sufficient data are available for wheat and rice to make a rough estimate of the global spread and output contribution of new technologies.

Dalrymple (1978) documented the spread of "high yielding varieties" of wheat and rice in the developing world since they were first released. He has updated that work as part of this study, and his update forms the basis for the following discussion. The precise numbers reported here differ from his, however, because he uses U.S. Department of Agriculture statistics as the basis for his estimates of total wheat and rice area while FAO statistics are used in this study.

Despite Dalrymple's efforts, complete time series are not available to show the spread of semi-dwarf wheat and rice varieties in all countries. For many countries the data show only a few scattered years. However, it is clear

that the semi-dwarf varieties continue to be grown and, indeed, continue to spread. In order to derive a consistent estimate of the total area planted to semi-dwarfs, an interpolation procedure is used based on the assumption that adoption took place smoothly over time (according to a fitted logistic function) for any periods for which data are missing beginning with the year in which the varieties are known to have been first grown and reaching the maximum reported level which is taken as the maximal asymptote etc. It is presumed that areas planted during the years for which data are not available followed the path of adoption observed in the sparse data. The parameters of the logistic function were estimated from the updated Dalrymple data but, since he does not use such a procedure, it is another source of difference between his estimates and those reported here.

6.3.1 Wheat

The wheat varieties developed by CIMMYT and its predecessor organization were shorter than the traditional wheat varieties; therein lay part of their ability to give high yields when provided with appropriate quantities of inputs. They were developed also to be resistant to the most important fungal diseases of wheat and were not sensitive to length of day in flowering ("non-photoperiod sensitive") and so were adaptable to a broad spectrum of growing conditions. Similarly, the rice varieties developed by IRRI, which became the basis for the ensuing joint work with national researchers, were shorter than traditional tropical rice varieties, giving them the genetic capability for high yields and resistance to lodging when grown with high fertilizer rates and good water control. Hence, both the improved wheats and improved rices are known as "semi-dwarf" modern varieties.

Over 260 varieties of semi-dwarf wheat had been named by 29 developing countries by 1984. Table 6.2 and Figure 6.3 summarize the data on their spread in the developing world since they were first introduced in 1965. By 1983 the international center-related wheat varieties had spread to over 48 million ha of land in the developing countries. This amounts to about 50 percent of the total area planted to wheat in those countries.

There has been a steady increase in the use of the modern wheats since their first introduction. Initial adoption was very rapid in a number of countries of Asia, reaching nearly 40 percent in India by 1970, and adoption has continued gradually since then. By 1983, India, Bangladesh, Nepal, Pakistan, Kenya, Argentina, Colombia, Mexico, Lebanon and Saudi Arabia all had over 80 percent of their wheat area in semi-dwarf varieties. Clearly, however, 100 percent is the limit to the proportion of area that can be covered. After that, continued improvements in the yield potential or pest resistance can provide continued yield improvements, but those advantages would not be reflected in aggregate data such as those shown in Table 6.2.

These semi-dwarf varieties have spread widely and, contrary to popular perceptions, are grown under dryland or rainfed conditions as well as with irrigation. Data to illustrate this are not available for many countries but some illustrative examples exist. In Bangladesh the area of semi-dwarf wheat increased from 20,000 ha in 1971-74 to 500,000 ha by 1980-81. There are no statistics on the exact area of rainfed semi-dwarfs but, even if it is assumed that all of the irrigated wheat area is devoted to semi-dwarfs, the minimal area in rainfed semi-dwarf wheat in Bangladesh was around 300,000 ha by 1980. Between 1980 and 1983 the global area in semi-dwarf wheats increased by over 10 million ha, with much of this increase occurring in China.

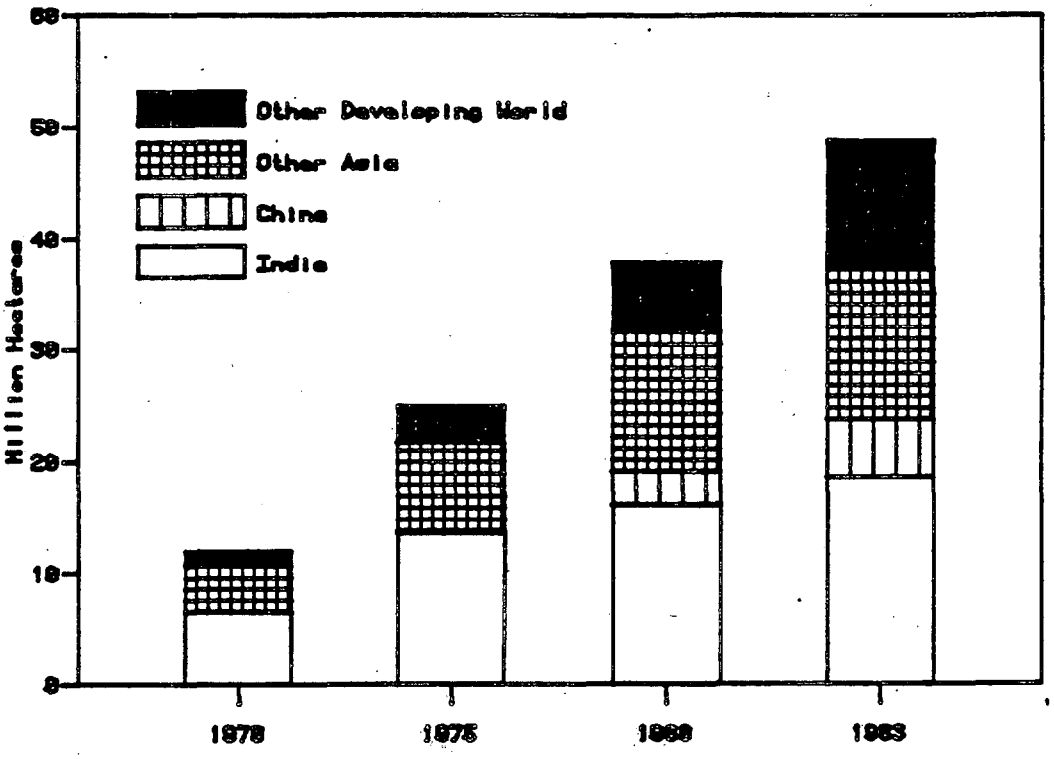
Table 6.2. Area Under Semi-Dwarf Wheat, 1970 and 1983.

Country	1970		1983	
	'000 ha	%	'000 ha	%
China	14.7	0.1	5126.0	17.8
India	6480.0	39.0	18550.0	80.1
Other Developing Asia	3458.6	40.1	7797.1	68.8
Afghanistan	232.0	10.5	400.0	13.3
Bangladesh			498.0	96.0
Nepal	98.3	49.2	377.6	92.1
Pakistan	3128.3	50.3	6521.5	88.2
Sub-Saharan Africa	69.8	5.0	556.3	52.1
Ethiopia	60.4	5.7	384.0	51.2
Kenya	7.9	5.3	83.8	72.9
Nigeria	1.0	33.3	10.0	71.4
Sudan		0.0	46.5	35.8
Tanzania		0.0	10.0	43.5
Zimbabwe	0.5	4.2	22.0	62.9
Latin America	794.5	10.8	8878.0	82.5
Argentina		0.0	6490.4	95.0
Bolivia	1.9	2.5	6.0	9.2
Brazil	56.1	3.1	826.5	43.0
Chile	61.2	8.3	329.7	70.0
Colombia	9.2	21.9	42.8	95.0
Ecuador		0.0	8.0	36.4
Guatemala	11.9	29.8	39.9	95.0
Mexico	651.9	88.1	942.5	95.2
Paraguay	2.1	6.6	6.0	8.0
Uruguay	0.2	.0	186.2	62.1
Middle East/ North Africa	1144.4	5.0	7690.3	33.8
Algeria	140.0	6.1	400.0	30.8
Egypt	0.0	0.0	306.2	53.7
Iran	63.0	1.3	891.7	14.7
Iraq	125.0	6.1	600.0	50.0
Libya	4.8	2.9	97.3	34.8
Morocco	90.0	4.6	721.6	36.5
Saudi Arabia		0.0	288.0	100.0
Syria	28.6	2.1	601.5	46.6
Tunisia	53.0	4.8	344.0	37.0
Turkey	640.0	7.4	3440.0	38.9
All Developing Countries	11962.0	14.0	48597.7	49.7

Source:Adapted from Dalrymple(1985).

Printed on 30-Aug-85

Figure 8.3
Area under semi-dwarf wheat, 1970-1983.



6.3.2 Rice

As with wheat, the first rices developed by IRRI using Taiwanese and other parents were a radically different type of plant from those traditionally grown. They were much shorter and would flower and produce grain any time during the year in the tropics, being non-photoperiod sensitive. The first group of these varieties (including IR8) was approved by the Philippine government for use by farmers in 1966 and, by 1969, three other varieties had been approved (IR5, IR20, and IR22). They and other genetic material from the international centers were made available to rice growing countries and, by 1972, a total of 19 IRRI-derived varieties (including the important IR36) had been named by national authorities. The rice research programs of CIAT, IITA and WARDA have produced a series of varieties named by national authorities, mostly in the regions in which they concentrate. By 1984 nearly 300 rice varieties had been named by national programs in 39 countries derived from or produced by the rice programs of the centers in collaboration with national researchers.

There has been a steady increase in the area planted to international center-related rices since their introduction in 1965. By 1975 they had spread to over 24 million ha, excluding the area of similar but independently developed rices in China (Figure 6.4). IRRI established working relations with China in the 1970s and, by 1983, IRRI varieties were being extensively used by Chinese researchers to produce the newest and highest yielding hybrid rices for that country. Even excluding these hybrids developed in China, center-derived rice varieties had spread to over 42 million ha by 1983, covering 70 percent or more of the rice land of Indonesia, Philippines, Sri Lanka, Senegal, Colombia, Honduras, Mexico, Nicaragua, Peru and Venezuela.

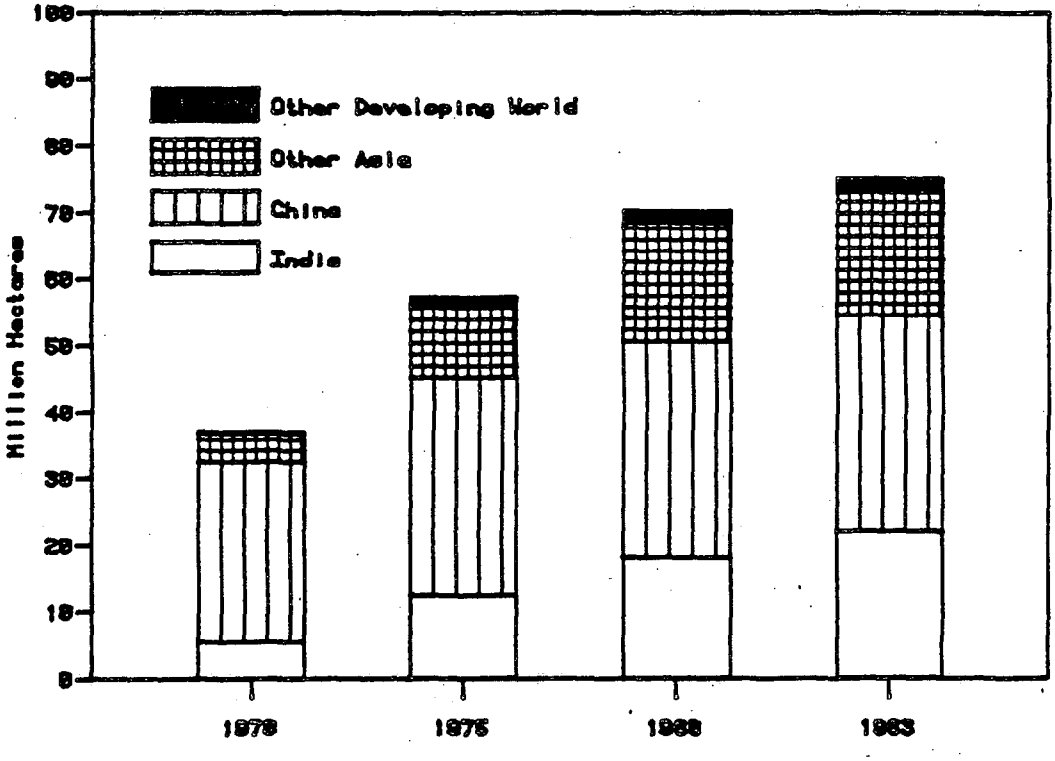
Table 6.3. Area Under Semi-Dwarf Rice, 1970 and 1983.

	1970		1983	
COUNTRY	'000 HA	%	'000 HA	%
China	26848.0	77.3	32265.2	95.0
India	5588.0	14.8	22180.0	54.1
Other Developing Asia	4281.5	10.0	19734.1	42.4
Bangladesh			2628.5	24.8
Burma	200.0	4.2	2370.1	50.4
Indonesia	1072.2	13.0	6626.9	72.8
Laos	53.6	6.0	9.7	1.4
Malaysia	164.6	23.3	254.8	36.4
Nepal	67.4	5.6	478.9	37.1
Pakistan	550.0	4.6	915.7	45.3
Philippines	1565.4	49.3	2757.0	83.5
S. Korea	2.7	0.2	418.6	34.1
Sri Lanka	73.6	11.2	749.7	81.0
Thailand	30.0	0.4	1200.0	12.8
Vietnam	502.0	20.1	1324.2	50.0
Sub-Saharan Africa	40.9	4.1	241.9	14.8
Camaroon			7.9	35.9
Ghana	36.8	89.8	35.0	43.8
Ivory Coast	2.1	0.7	32.7	7.1
Nigeria	1.0	0.4	60.0	10.0
Senegal	1.0	1.1	72.4	96.5
Sierra Leone			33.9	8.5
Latin America	252.4	4.2	1831.7	27.8
Argentina			27.3	33.7
Brazil			729.1	14.3
Colombia	41.0	17.4	364.3	91.8
Ecuador	15.7	10.5	40.3	53.1
Guatemala			3.5	29.2
Guyana			43.5	59.5
Haiti			11.0	22.0
Honduras	0.9	4.7	21.4	89.2
Mexico	123.3	66.6	154.2	83.4
Nicaragua	9.1	33.7	37.1	78.9
Panama	40.6	31.2	55.2	69.0
Paraguay	0.2	1.5	21.9	64.4
Peru	16.9	12.8	140.7	74.1
Surinam	4.7	13.1	48.7	69.6
Venezuela			133.5	79.9
Middle East/ North Africa	2.1	0.3	80.7	11.0
Egypt	2.1	0.4	20.7	4.9
Iran			60.0	19.2
All Developing Countries	37012.9	30.1	76333.6	58.5

Source: Adapted from Dalrymple(1985).

Printed on 30-Aug

Figure 6.4
Area under semi-dwarf rice, 1970-1983.



Including the Chinese area, semi-dwarfs had spread to over 75 million ha or 57 percent of rice area in the developing countries by that year.

6.4 Centers' Breeding Approaches

6.4.1 Plant breeding and productivity

There are three components of technical advance in crop production: environmental (E), genetic (G) and interactive (G x E). The E component is mainly husbandry (tillage, weed control, disease control and so forth) but it contains also a social element, namely the acceptability of a variety to the consumer. The G component is plant breeding, genetic advance that enhances yield, disease resistance (best thought of as protection of yield), adaptation to local environments and/or cultural practices, and quality as perceived by consumers, usually through markets. The GE (interaction) component relates to the differential performance of genotypes (varieties) in diverse environments, both physical and social. It may be exemplified by pairs of contrasted varieties that differ in, for example: yield in sites contrasted as to length of growing season; yield in the presence/absence of a disease; yield in the presence/absence of different cultural practices; and market adaptation including preferences, for tastes, textures, colors, cooking and processing characteristics.

The socio-agricultural environments of crops vary in both space and time. In space, they range from fairly uniform over quite large areas (as with IRRI paddy rices in which varieties do well over large areas and suit large markets) to very small (as with many tropical food crops, in which physical environments and local markets may be extremely restricted).

Environments vary in time, too, maybe imperceptibly over short periods but cumulatively very greatly. North temperate cereal yields have roughly doubled over the past 40 years, partly as a consequence of enhanced husbandry (with fertilizers, herbicides, machinery, disease and pest control as major components). Genotypic adaptation to such secular changes is no less necessary than it is for spatially distributed variation. Historically, indeed, the semi-dwarf small-grain cereals and the temperate maizes tolerant of high-density planting, developed in association with the changing husbandries. The modern wheats and rices represented an exactly analogous exploitation of a grand scale GE effect. Historically, in north temperate agriculture, it is unclear whether the changing husbandry pulled the breeding of adapted varieties as a response or whether the breeding evoked the husbandry (or a little of each). In the case of semi-dwarf rices and wheats, there is no doubt that the G, E and GE parts were generated collectively as "packages". Whatever the history (chapter 8), the importance of the GE effect is plain - neither varieties nor husbandries could have succeeded on their own (Simmonds 1981).

Most of the literature of GE effects in plant breeding relates to yields, and this character is indeed all-pervasive and often dominant in breeding programs. But the final judgement of value of a variety is based upon "general worth", a complex character that includes socio-economic features as well as yield, often with tradeoffs between components: a low yielding variety may be acceptable if it does not need to be sprayed or is especially early or drought-resistant or has exceptional quality; and a poor quality variety may be acceptable if it is very high yielding (as IR8 rice, with its "chalky" grain was widely accepted in Asia). Food-crop breeders, especially breeders serving myriads of tropical small-scale farmers in

exceedingly diverse agricultural and socio-economic circumstances, cannot afford to exclude the socio-economic component in the environment encountered by a plant variety. For them, GE interactions and the intrusion of explicit socio- economic features into "general worth" are all-pervasive realities. The more diverse the socio-agricultural environments to be served, the more important GE effects are likely to be. Plant breeding, in short, is, of its nature, highly locational specific. Really widely adapted varieties are only likely to appear in relation to exceptionally uniform environments: diverse environments demand diverse varieties.

6.4.2 Issues in operational breeding work

Operational features of the centers in relation to crop production include several common features. The effort is divided roughly half-and-half between breeding (G) and husbandry (E) studies. Breeding authority is fairly highly centralized, with a "lead center" for a particular crop, working with outstations and collaborating institutes in other territories. The general style is "the package" of the modern variety plus the kit of treatments to go with it. This implies at least some degree of acceptance of the notion that substantial advance (on the model of earlier successes with modern varieties) must depend upon G + E + GE effects jointly. Breeding and selection take place largely on the experiment stations of the world under relatively good conditions of moisture, fertility, weed control and pest and disease control. In short, material is generally selected under rather high levels of inputs which for many important environments, such as temperate wheat lands, may be quite an appropriate procedure. Occasional efforts partly to mimic farm conditions are made, however (e.g., CIAT grows beans on maize at diverse spacings), and some low-input trials are done (e.g., CIMMYT maize). Sometimes, "shuttle breeding" (a CIMMYT term) is practised, partly to

accelerate the program by taking two or more generations a year but also to diversify the selection environments in hope of generating wide adaptation among the products.

The products of breeding emerge as numerous lines/populations/clones, all showing some promise in the original selection site(s), which are then subjected to multilocational testing in diverse sites, by a center itself, by collaborating centers and by national agricultural research systems. The intention is that such testing shall reveal not only widely adapted varieties but also local adaptation (i.e., shall exploit a GE effect) where it exists. Any potentially good varieties so revealed are then freely available for local exploitation by any appropriate means that presents itself. Trial results, returned to the breeders, help to guide future activities. Multilocational testing is operationally feasible for most seed propagated annual crops but for clonal crops is severely obstructed by quarantine regulations. There has been some rather restricted exchange of cassava material. If the CGIAR system handled clonal perennials (in effect, it does not), the problems and delays would be even worse.

The genetic base of breeding stocks is, with varying degrees of commitment to the idea, kept wide in the hope of generating enough variability among the products to meet the unforseeable GE effects that become apparent in the form of local adaptation. Also with a varying degree of commitment, breeding in the centers is linked to genetic resource conservation work, a natural starting point for a wide breeding base and a natural source for specific genes (especially disease resistances).

The principle of development is widely accepted. That is, varieties picked by national systems from multilocational trials can be used either as local varieties or as parents in national breeding programs, or as both. In parallel, a center can and does respond to expressed national interest in particular parental combinations or plant characters. The expectation is that, in the longer run, plant breeding will largely devolve to national systems (presumably leaving the centers to genetic resources work, population development and training activities).

There is pressure on breeders (as there is on other research people in the centers) to produce "practical" results. This is a sociological fact that has several undesirable side effects, notably: an oft-noted tendency to glossy publicity, a failure to make critical contributions to plant breeding ideas, and a tendency to take some quick and easy but not necessarily best ways.

6.4.3 Criticisms of centers' breeding strategies

The CGIAR was probably founded in the hope that more green revolutions would follow the achievements of the Ford and Rockefeller Foundations through modern wheats and rices. They did not; nor were they to be expected because the biological and social preconditions were simply not there. Tropical foodcrop agriculture (irrigated wheat and rice farming excepted) is mostly a complex mosaic of rather local physical environments, cropping patterns, cultural practices and socio-economic circumstances. The centers (and the national systems with which they collaborate) have, therefore, had to settle down to the ordinary hard work of agricultural research, of hard-won stepwise changes in husbandry and varieties. "Breakthroughs" are not, or are but very rarely, in prospect.

Criticisms may be made of plant breeding in the centers despite the large scale and high professionalism of much center breeding. Programs have a tendency to be over-centralized. It may not be sensible merely to produce flows of diverse materials through one or a few environmental "bottlenecks" and hope that the products will either be widely adapted or capable of meeting many demands for specific local adaptation. There is a limit to the number of diseases that can be coped with in one place. More generally, centralized decisions as to parents and breeding plans are certain to be wrong for most places most of the time, unless GE effects can be ignored, which they cannot.

The natural short-term response to a troublesome disease is to use any available major gene resistance, usually a pathotype-specific vertical resistance (Simmonds 1983). This may work for airborne pathogens, but it is hazardous. A new pathotype may (and probably will) emerge and the vertifolia effect of Van der Plank may make the last state worse than the first. To breed in such a way as knowingly to incur the risk of renewed epidemics in food crops can surely not be correct in the long run, even if it is sometimes inescapable in the short run. Yet there seems too little consciousness of the alternative (horizontal resistance) or of the need for back-up breeding to construct horizontal resistance. Perhaps the consciousness is growing and it has to be said that many temperate plant breeding programs seem not very aware either. Rich countries, however, can stand epidemics that would be disastrous for subsistence farmers.

If the object is to breed varieties for small-scale farmers employing low inputs, a procedure of selection under high input conditions on experiment stations is likely to be self-defeating. It is not good enough simply to do odd trials, later on, at low inputs if parents have been chosen and progeny

selected in contrasted environments. The failing is a failure of perception of the force of GE effects. Most plant breeders in rich temperate countries do not face this problem because they are breeding for high-input agricultures. The practical problem before the centers, of making selection environments more realistic, will not easily be solved. Some center breeders are conscious of the problem and are trying to attack it; others are not.

Related to this preceding point, but rather wider, is the matter of farming systems perspective. Plant varieties are bred for "general worth" in particular socio-agricultural environments. If breeders misperceive the environment, their varieties are unlikely to do well. Breeders cannot know too much about the agricultures they seek to serve, but that knowledge is not acquired on the experiment station. Substantial proportions of maize in tropical America and of sorghum in Africa are both food-grain crops and supports for cash crops (beans and yams, respectively). Farmers want tall, strong, widely spaced cereal plants, not small, slim closely spaced ones. CIAT bean breeders select their beans on maize but maize or sorghum breeders seemingly do not select their cereals with cash crops hanging on them. Perhaps they should? Sufficient attention to the main agricultural reality of dryland barleys grazed by sheep in the spring is only slowly being paid by breeders at ICARDA.

There are perhaps too many gimmicks related to public relations activity and the need for "breakthroughs", to the over-practicality of much of the work, and to intolerant scepticism of criticisms. CIP's potatoes from "true seed", for example, may fall into this category. Some observers believe that there may be few actions that could confer greater benefit on the centers than the banning of glossy reports and other sub-literature, and the promotion of

orderly scientific publication in properly referred journals (for all their imperfections).

6.5 Change in Food Production

The modern, semi-dwarf varieties of wheat and rice give more or less higher yields than traditional types under both experiment-station conditions and most of millions of hectares on which they are being grown by farmers. There are, clearly, some farmers' conditions under which they are less productive than traditional varieties, and there farmers continue to grow traditional varieties. Those farmers who have done so have felt that they should grow the new varieties because they are perceived (through their observation and perhaps also extension propaganda) to be more productive than other available varieties. Their contribution to food production depends on how much yield advantage they have over traditional varieties. While it is clear that they must have such an advantage, or else farmers would not grow them, it is not clear exactly how large that advantage is. Data bearing on the question are examined, with results reported in the next two subsections.

6.5.1 Wheat grain yields

The initial semi-dwarf wheats raised the yield potential under experiment-experiment station conditions from 4 t/ha to the 7-8 t/ha range. Since their first development and release in the early 1960s, their yield potential has gradually been increased to the 8-9 t/ha range. The exact degree of yield advantage over "traditional", tall varieties is no longer an issue for much research attention because of the degree to which the new varieties have replaced the old. Data are available that illustrate their continued improvement: during the three-year period 1980-82, international

comparisons of the most advanced wheat lines ("Veery" lines) with the best locally grown varieties (i.e., the "local checks", most of which were also semi-dwarf), showed that the Verry lines outyielded the best local check variety by about 10 percent on average, and outyielded the best local check in 65 percent of the developing country locations (CIMMYT 1983, p. 19). One indication of the value of these lines is that, by 1984, twelve varieties based on these lines had been named by national programs in Chile, Mexico, Portugal, Pakistan, Paraguay, South Africa, Spain, Zambia, and Zimbabwe.

Few recent yield comparisons of semi-dwarf and traditional wheats grown in farmers fields are available, but earlier research suggested that yields of the semi-dwarf wheat varieties give between 30 percent and 200 percent higher yields than traditional varieties. Statistics from India, covering the period between 1966 and 1973, when adoption increased to over 50 percent of area, showed that the new wheats give yields "from less than two times to more than three times as high as traditional varieties" (Dalrymple 1975, p. 25). Farm level data from six large-scale studies in India showed that the new wheats gave average yields 80 percent higher than the local varieties (Vyas 1975). An analysis of farm-level data from Tunisia showed that farmers growing the semi-dwarf varieties with the average level of inputs had 20 percent higher yields than farmers growing traditional varieties using the same level of inputs (Gafsi 1976). Similar farm-level data for Turkey showed that farmers growing the new varieties had 40 percent higher yields than those growing other varieties (Demir 1976). The absolute yield advantage of the new varieties over the old in these studies ranged from 350 kg/ha in Tunisia to 1100 kg/ha in India, suggesting that an average difference of 500 kg/ha between new and old varieties, as grown by farmers, would be a conservative estimate.

6.5.2 Rice grain yields

The yield advantage of modern varieties of rice can be estimated from some national statistics in a few countries that keep such statistics. Between 1968 and 1977, the modern varieties gave an average of 100 percent higher yield than traditional rice varieties in India; in Bangladesh they gave 160 percent more than local varieties; in the Philippines and Indonesia they gave 30 percent more than the traditional varieties (Herdt and Barker 1985). These differences may reflect, in part, the fact that the new varieties were initially grown under relatively favorable, high-quality land conditions in India and Bangladesh so that the differences between the yields with new and old were large, while in the Philippines and Indonesia, the varieties were suited to a much broader range of conditions, with a smaller average yield advantage.

Farm-level comparisons of new and old varieties have been carried out in many Asian rice growing countries. One review of farm-level studies found that the yield advantage of modern varieties varied from 10 to 158 percent (Dalrymple 1977). Another review of studies covering 28 locations showed that the new varieties outyielded the traditional ones by 10 to 100 percent, averaging 40 percent higher yield (Herdt and Barker 1985). On this basis 600 kg/ha would be a conservative estimate of the average yield advantage of modern rices over the traditional. Farm yields of rice include the inedible (but still valuable as fuel) hulls, which account for about one-third, so the yield advantage converts to 400 kg/ha of edible cereal grain.

6.5.3 Production advantage

New varieties are usually grown under better land conditions because they have the potential to give higher yields if provided with good growing conditions while the old varieties do not respond as much to advantageous growing conditions. For this reason, most of the irrigated rice and wheat land is planted to new varieties and, for the same reason, the new varieties are grown with higher rates of fertilizer, and with greater attention to weed control by farmers. In many cases, these are provided from additional organic manures and additional family labor, as, for example, in India, China and Bangladesh. It is also clear that, both from experimental evidence and farmers' experiences, application of chemical fertilizers is highly productive and profitable on these varieties and, because governments want the increased food that can be produced using them, fertilizers are made available and applied. In areas where labor is plentiful, additional labor is used for weeding but, where it is less available or more costly, farmers seek alternative means of weed control, through cultivation or herbicides. The idea that modern varieties "require" more inputs than the old ones is not substantiated — they respond to higher levels but do not require them. Equivalently, while modern varieties respond profitably to higher input levels, the yield advantage is not lost if for any reason these inputs are not provided.

These additional inputs contribute to production, so the entire production increase cannot be attributed to varieties alone but, on the other hand, without the productivity gains available from the combination of varieties and inputs, there would have been little reason to use higher levels of inputs. Thus, it does seem reasonable to attribute the value of extra production, less the costs of extra inputs, to the new varieties.

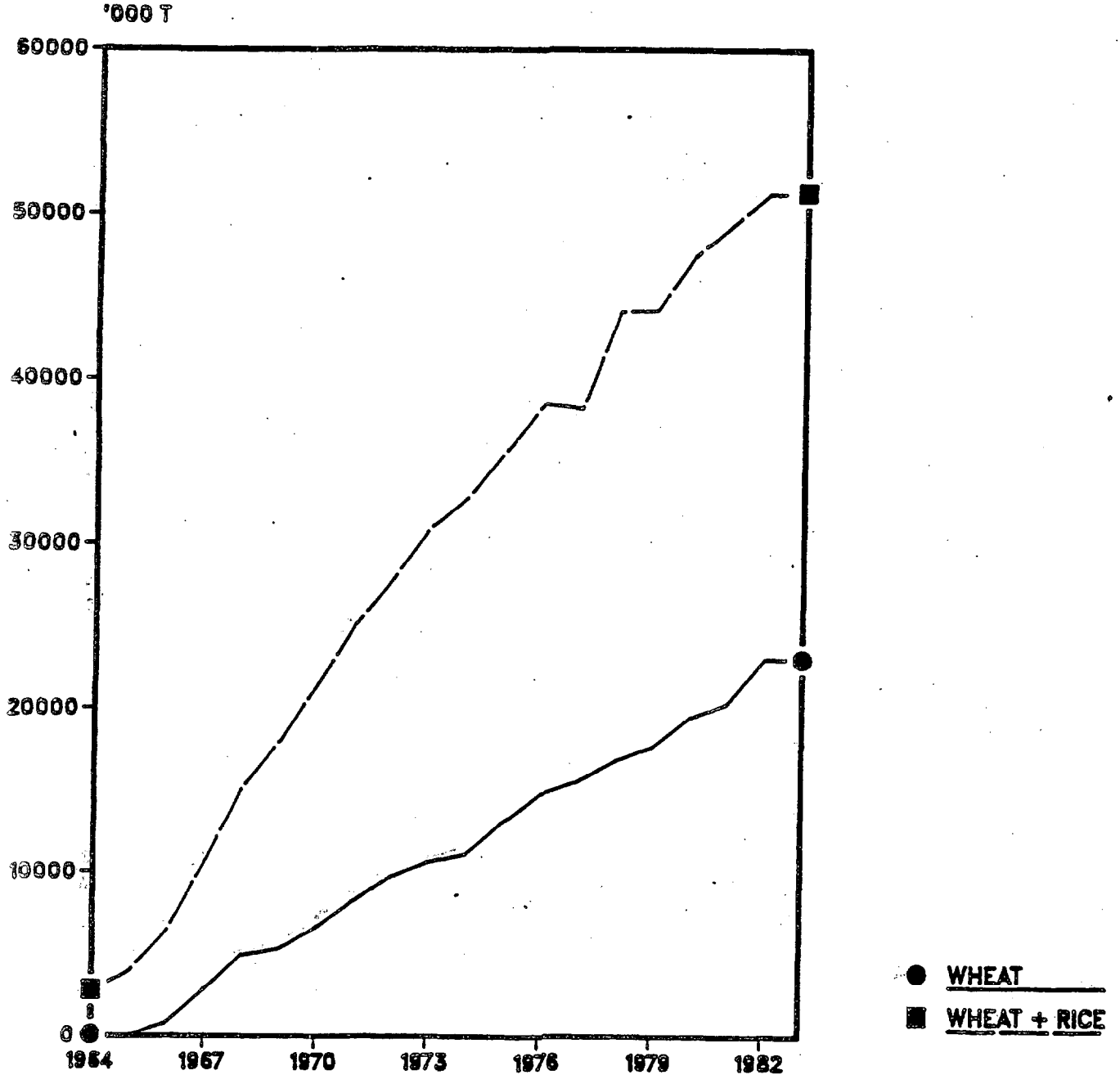
By 1965 and 1970, farmers in the developing countries other than China adopted modern wheats on approximately 11 million ha and modern rices on an estimated 10.3 million ha; with China included, the area of semi-dwarf rice was 37 million ha. The additional food production made possible by the new semi-dwarf varieties in 1970 was about 21.5 million tons (Mt) of grain (Figure 6.5). By 1983, the latest year for which data are available, the area of modern wheat, excluding China's area, was 43.6 million ha, the area of modern rice outside China was 42.9 million ha and the increased food production made possible from these varieties was 38.9 Mt. Including China, the modern wheat varieties were planted on over 48 million ha in the developing world in 1983, modern rices on over 75 million ha, and the estimated increase in food production amounts over 50 Mt, enough to provide the average grain consumption levels for over 500 million developing country people.

6.5.4 Farm-level productivity gains

Governments have limited power and they choose to take even more limited power to encourage farmers to use given production technologies, so widespread adoption of a technology is evidence that farmers find it preferable to the available alternatives. Conversely, the lack of adoption indicates that, under farmers' conditions, particular technology is no better than available alternatives, perhaps because of the lack of some key complementary inputs or of a ready market, or for some other reasons not strictly related to the characteristics of the technology.

Figure 6.5

ESTIMATED ADDITIONAL FOOD PRODUCED BY SEMI-DWARF WHEAT AND RICE IN ALL DEVELOPING COUNTRIES



Feature: Rice in Luzon, Philippines

Two samples of rice farmers in the most advanced intensive producing areas of Luzon, Philippines were interviewed, one in 1965 and one in 1966, before the introduction of semi-dwarf rices and again at 4-5 year intervals until 1982. The proportion growing modern varieties of rices increased from none in 1964 to an average of 63 percent in 1970, 76 percent in 1974, and over 95 percent in 1981-82. The proportion of the sample farmers using fertilizer on their rice increased from 60 percent in the initial year to over 95 percent in 1982, the proportion using insecticides increased from 31 percent to 92 percent, and the proportion using herbicides increased from 12 percent to 74 percent. Thus these data show that adoption of modern varieties occurred more rapidly than adoption of other technologies, even though the process had started earlier for the other technologies.

Over the period, the average cost of the material inputs increased from 53 pesos to 988 pesos per ha, but inflation accounted for much of the increase in costs and returns over the period. For example, the price of rice increased from 0.43 pesos per kg in 1964 to 1.27 pesos per kg in 1982. Converting all values to their equivalent in terms of kilograms of rice makes it possible to abstract somewhat from the price changes to see the effect of the changes in inputs used and the effects of the technology. The choice of the major staple food as the deflator is somewhat arbitrary although convenient. Given that it has been subjected to price reductions due to increases in supply it is not a conservative deflator (although it is more so than, say, hand calculators or computers) but is indicative and, it is believed, instructive.

Output averaged 2280 kg/ha in 1964 and increased to 4200 kg/ha in 1982. The cost of the material inputs in terms of rice equivalent increased from 120 kg/ha to 780 kg/ha. As a result, the quantity of rice left after paying for the inputs used with the new technology increased from 2160 kg/ha to 3240 kg/ha. Of course, farmers have other costs — land, labor and capital services — which they purchase, so the entire amount left after paying for inputs is not profit, but clearly the output of rice increased by far more than the cost of inputs.

When all paid out costs are deducted from production, the amount remaining (farm family earnings) reflects what the farm family can consume or sell and convert into cash income. Two major changes that increased farm family earnings were higher yields and lower land rents resulting from land reform. Increased payments for current inputs, hired labor and hired machinery reduced cash earnings. The net result was an increase from an average of 860 kg/ha in 1966 to 1570 kg/ha in 1982, representing an almost doubling in the quantity of disposable rice available to the family.

END FEATURE

It has been argued occasionally that the inputs used with "green revolution" technologies are so costly that their use leaves farmers worse off. If the technology is so widely used as to reduce the market price by more than it reduces unit costs, farmers as a group may be worse off, or in the more usual case, non-adopting farmers are made worse off by even modest price reduction (see section 6.5.5). But it is difficult to see how any farmer would willingly continue the use of new technologies if they raise unit costs in the first instance. Because every situation is different and because there are relatively few studies that provide such details, it is impossible to give comprehensive data on this issue, but the case of Philippine rice farmers discussed in the accompanying feature is instructive.

Where input prices of modern inputs have increased, farmers can make the choice not to apply such inputs. The real costs of inputs used with the new technology have not generally increased on the world market. While it is true that world fertilizer prices increased sharply between 1973 and 1975, thereafter they declined sharply, and in 1983 were just about equal to their 1976 level in real terms (World Bank 1984). On the other hand, these prices are in US dollar terms, and countries whose currencies have devalued relative to the dollar and which depend on the export of commodities which have experienced depressed prices in recent years, have had increasing difficulty paying for imported inputs in the 1980s. They would be in still more difficult positions if they had to import the food they are now able to produce with the new technologies available.

One possibility, which the concerned countries hardly rate as a real option, is to cease importing inputs and to produce using only domestically available inputs. The problem is that there are no technologies for growing

food crops without supplying plants their essential nutrients, often from mineral fertilizers that may not be manufactured locally. The suggestion that plant breeders at the international centers should produce varieties that give high yields without additional nutrients is unrealistic. There may be ways to make the process more efficient, and these are being pursued; but a minimum of nutrients will have to be obtained from some source ("organic" farming?) if productivity is to be sustained.

6.5.5 Implications of widespread adoption

When many farmers adopt a new technology, the total availability of the commodity may increase at a more rapid rate than demand, with the result that the commodity's price tends to fall. This mechanism transfers benefits to consumers of the product and, in the cases of modern wheat and rice varieties, has been important for providing substantial benefits to poor consumers, as is discussed in chapter 8.

The fall in the price of commodities resulting from widespread technical change is different from a fall in prices caused by large, subsidized imports, or government rationing and price controls. In the case of the latter two policies, there is no way farmers can avoid the effect of the fall in prices to obtain a constant or increased return to their family resources. With technical change, however, costs of production per unit fall and so, even if prices fall, it may still be possible for farmers to achieve adequate returns. Indeed, some may be encouraged to adapt the new ways in order to maintain incomes as prices decline.

Some observers automatically associate labor-displacing machinery with the idea of modern technology. But in the case of the new wheat and rice

varieties, there is no more reason to use machinery in production than with the varieties they replace, and where machinery has accompanied the adoption of new varieties, its use has been motivated by other reasons. There is some incentive to use machinery for harvesting and postharvest operations if farmers have the opportunity to use their land for a second cropping season. The machines may help to harvest more quickly and thus to facilitate planting the next crop. However, the evidence suggests that machinery is not necessary for increasing output, and that its absence has not slowed the rate of increase of food production.

On the other hand, there is considerable evidence that the introduction of new wheat and rice varieties has been associated with increases of labor use on the order of 25 percent for a single crop in many areas, much of the additional labor being hired. However, even where, in aggregate, labor demand is increasing, certain categories of labor may be disadvantaged, especially where modern technologies have been associated with changes in the organization of production in conditions of gender-specific task allocating and have led to increases in unpaid female labor or decreases in remunerative work opportunities for women. There is also evidence that the new varieties have allowed a substantial increase in the proportion of land that is double cropped. A dramatic case is that of wheat in Bangladesh.

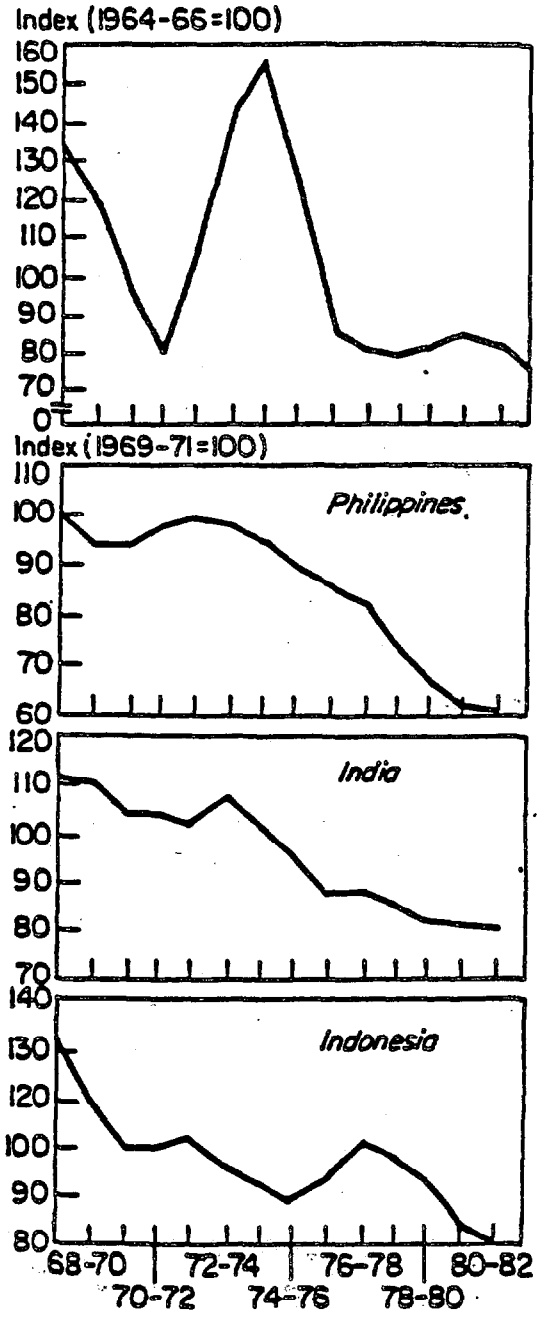
Prior to the availability of short-duration adapted varieties, about 100,000 ha of land were planted to wheat each year in Bangladesh. Since 1975-76 wheat production has increased at the astounding rate of 50 percent per year, largely on land that had previously remained in fallow during the winter season. By 1981, over half a million hectares of land were planted to wheat in the country and over 1 Mt of wheat were being produced annually. Because

much of this wheat was planted on land that had been in fallow, the labor needed for its cultivation represented a net increase in employment.

One of the clearest predictions of economics is that, other things unchanged, the price of rice and wheat should be expected to decline in the [illegible]ce of widespread technological change such as has been experienced with the semi-dwarf varieties. Wheat prices in many developing countries are closely related to world wheat prices because of large imports, but rice prices are isolated from the world market in many countries. Figure 6.6 shows some data on domestic rice prices in a number of Asian countries where technical change in rice has been rapid. There has been a reduction in domestic prices as a result of the technical change. Consumers are able to obtain their food requirements at lower costs than would otherwise have been the case. This is a major benefit of technical change (it is discussed more extensively in chapters 8). Some farmers who have used the new technologies are able to offset the lower prices received by their higher output and consequently lower costs per unit produced. Some other farmers growing the same products who have been unable to adopt the new technologies are worse off because they receive lower prices but have no change in costs.

These and other effects of widespread adoption of new varieties quickly become difficult or impossible to follow through an economy because they interact with other changes that are also occurring (chapter 8). Rapid population growth may drive up food needs and labor supply, changes in world prices of an export commodity may increase the demand for inputs which may raise their prices, a weak industrial sector may have little demand for labor so that more workers must seek employment in agriculture, distribution of income generated by new industrial activities may be highly concentrated

Figure 6.6



Trends in real world rice price and in rice price to consumers in selected, formerly rice importing, countries.

thereby generating strong demand for imported goods and little effective extra demand for agricultural products (chapter 1). In the face of these and other changes it is challenging indeed to trace clearly the complex changes caused by changing technologies in agriculture in general and by those that have some association with a center in particular. The economic and social impacts consist of positive and negative elements with gainers and losers often to be found in different parts of the economy and the agro-ecosystems that are farmed. A socially sensitive policy on technological change in general, and on agricultural research in particular, can go far to minimize the negative effects, especially on those who can least afford to lose. Many of the possibilities relevant to the poverty-oriented work of the centers are noted in chapter 8.

6.6 Change in Stability

The types and severity of risks confronting farmers vary greatly according to the farming system, and to the climatological, policy, and institutional setting. Nevertheless, agricultural risks seem to be prevalent throughout most of the world. They are particularly burdensome to operators of small farms in developing countries, and hence the impact of adopting new technologies is of concern. These farmers, typically being averse to risks, seek to avoid them through various managerial and institutional mechanisms. For example, they may diversify their crops, favor traditional farming techniques using fewer modern inputs, and enter into sharecropping arrangements.

The growth of foodgrain production in recent decades has in most countries been accompanied by increases in variability at the national level (dispersion about trend). For example, in India, the variance of national

cereal production around trend increased by 240 percent between the 1952/3 to 1964/5 period prior to the introduction of semi-dwarfs and the 1967/8 to 1977/8 period after their introduction. Sixty percent of the increase was due to increased variability of planted area while 40 percent could be attributed to increased yield variability (Hazell 1984). Increases in yield variability appear to be related to greater price and rainfall variability and more erratic supplies of electricity for irrigation as well as changes in varieties. In many biological systems variance is positively related to mean output so that some of the increase on variance will be an automatic concomitant of increase in mean yield.

Increased yield correlation for foodgrain production between regions in other countries, including the industrial countries, is also apparent for rice, wheat and maize (Hazell 1985). The changes are less pronounced in developing countries than in the U.S.A., and they may result from economic as well as technological factors. However, to the extent that they arise from a narrowing genetic base, unless steps are taken to cultivate a wider diversity of genotypes, the problem could become more pronounced in these countries in the years ahead. The problem may be aggravated further as opportunities for exploiting new arable land and irrigation become more confined, and production growth depends increasingly on yield-improving technologies.

Since much of this variability is unpredictable for all the economic agents involved, it increases risk. Should these changes increase the adversity of life among the poor, they are relevant to a wider assessment of the impact of the centers' contributions to production.

There is no question that the growth in foodgrain production made possible by semi-dwarf varieties has been desirable in most countries for meeting increases in demand and lowering prices. However, increased domestic production variability is usually reflected in increased market and price instability which, in the absence of government intervention, can pose difficult problems for low income people. It also increases the size of emergency food stocks that need to be carried within countries to ensure that consumption does not fall precipitately.

Some researchers (e.g., Barker, Gabler and Winkelmann 1981, Mehra 1981) have attributed much of this increased production instability to the modern variety and fertilizer based technologies, particularly in developing countries. The yields of crops grown with the new technologies may be more sensitive to weather and disease. Because higher levels of purchased inputs are used, their yields may also be sensitive to year-to-year variations in access to inputs use arising from frequent price changes and climatic variation, or from supply restrictions.

Mehra (1981) has provided some support for the view that new technologies for cotton and hybrid pearl millet have increased yield variability for farmers, particularly in arid regions with limited irrigation. Consequently, the potential importance of breeding for more stable yields if farmers are to continue to find new technologies attractive for adoption. This concern may be especially relevant for coarse grains in Africa and the semi-arid tropical areas of Asia where new technologies tend to offer less favorable increases in mean yields to compensate farmers for the possibly higher yield and investment risks involved.

The importance of the new technologies in increasing the variability of national foodgrain production is less clear than it might be because many other factors also contribute to variability at the aggregate level. Clarification is being sought, especially by concerned centers, and a conference organized by IFPRI in November 1985 addressed these important issues too late for inclusion in the present volume.

6.7 Coda

* Plant breeding is a time consuming process: existing varieties, breeders' lines, mutant stocks and land races are collected, studied and crossed. Early generations "segregate" in reaction to particular stresses. Plants are purposively subjected to a series of stresses thereby identifying resistant plants by screening. The process is time consuming because one season is required to grow each generation, and because screening for different characters is often carried out sequentially.

* After five to seven generations of selection pressure, a line may be ready for preliminary testing. Thereafter, advanced lines may be entered in trials in a number of locations. Additional time is required for national authorities to test and evaluate the suitability of materials for their conditions. The minimal time required is five to eight years between initiation of a crossing program, and identification of promising varieties. The research that led to the release of CIMMYT wheats in the mid-1960s, for example, began 20 years earlier in Mexico and elsewhere.

* Centers that began breeding programs in the late 1960s on field beans, cassava, cowpeas, chickpeas, tropical sorghum, pearl millet and tropical pastures had to begin by collecting germplasm and determining how the existing varieties could be improved.

* By 1984 over 200 varieties each of wheat, rice and maize related to center efforts had been released by developing countries; more than 20 developing countries had named a total of 96 bean varieties related to center research; 16 countries had named 63 cassava varieties developed in cooperation with the centers; 23 developing countries had named 61 center-related potato varieties; over 30 center-related sorghum varieties had been named by countries. These new varieties are all being produced by farmers and are contributing to food production in a noticeable way.

* Countries in Africa have named over 50 center-related maize varieties, countries in Asia nearly this number, and countries in Latin America nearly 100. These new maize varieties are estimated to have spread to over 6 million ha by 1984.

* Varieties of barley, cowpeas, chickpeas, pasture species, pearl millet, durum wheat, and pigeonpea have also been named by national authorities and are beginning to be grown by farmers in the developing world.

* The bulk of the increased food production resulting from centers' research has been from wheat and rice. By 1983 the international center-related wheat varieties had spread to an estimated 48 million ha of land in the developing countries. This amounts to nearly 50 percent of the total area planted to wheat in those countries.

* Excluding semi-dwarf varieties developed in China, center-related rice varieties had spread to over 40 million ha by 1983; including the Chinese area, semi-dwarf rice had spread to over 75 million ha of rice in the developing countries.

* New wheats probably give an average yield of about 500 kg/ha over old varieties as grown by farmers; 600 kg/ha is a similarly conservative estimate of the average yield advantage of modern rices compared to the traditional. Allowing for the inedible hull, this converts to 400 kg/ha of extra food grain. Including China, the modern wheat and modern rice varieties gave an estimated increase in food production of over 50 Mt to provide the average grain consumption level for over 500 million people.

* Variability of production is controversial to measure but, by most indicators, has increased along with the average levels of foodgrain production. There are implications for storage and trade policy as well as for plant breeders in their continuing quest for greater stability in varietal performance through resistance to pests and diseases and tolerance of other environmental stresses.

7 HUSBANDRY AND METHODS

7 HUSBANDRY AND METHODS

7.1 Introduction

The goal of research at the centers, in their collaborative programs and in the national systems, is to develop improved agricultural technologies. Major impacts have resulted from improved germplasm, but methods and programs other than plant breeding are also important. Such research has resulted in diverse technologies that range from new machines, through better management of experiment stations and breeding programs, to methods of producing disease-free planting material. Only relatively few such technologies were in widespread enough use by farmers in mid-1984 to have generated an impact at the farm level. These provide the focus for this chapter's discussion.

The collaborative research on non-germplasm technologies is analogous to that discussed in the previous chapter. There are joint research projects between the national systems and the centers, and also between cooperating national systems. There are regional networks of researchers to move technologies and ideas between countries. Center staff posted in countries in institution-building projects are another common form of collaboration. Center prototypes or blueprints for machinery are adapted to local conditions by agricultural engineering programs in the national systems. In chapter 13 the contributions of centers in plant protection are discussed while chapter 16 covers farming systems and chapter 17 presents the results of research on machinery, so those types of technology are not dealt with in detail in this chapter.

It is more difficult to develop estimates of the impact of management technology than of germplasm technology. Quantitative data on the spread of these technologies and of their impact on output and productivity are seldom collected. In addition, the problems of attribution are even more difficult for many of these technologies than for varieties. For example, what portion of social benefits are attributable to center-related research on integrated pest management techniques that include using a pesticide developed by a company which a center tested and found effective, with management techniques promoted by national extension programs?

Another example of these difficulties is an area where the centers have had a major impact, namely crop management. In the early days of the green revolution, modern varieties were promoted along with a "package" of practices which were developed collaboratively between the international centers and national systems. These packages were supposed to give farmers maximal returns from the use of the new varieties. The packages were promoted through extension, and frequently also through large-scale production programs which included subsidies for the inputs and sometimes, credit. The precise packages recommended by governments were nearly always rejected by farmers because they were not ideally suited to their soil, climate, goals or market conditions. But the principal inputs in the package were accepted - the seed, much of the fertilizer, and some of the recommended management practices.

With the desire to quantify the benefits juxtaposed against the problems of quantification and attribution, some selected examples of the quantitative impact on output and productivity of some technologies other than germplasm are given. No attempt is made to estimate the aggregate impact. The criteria

for selecting examples have been (a) clear links of the technology to the centers, (b) sufficient adoption by farmers to detect an impact of the technology, and (c) a range of different types of technology.

7.2 Output Effects of Specific Innovations

7.2.1 Diffused light potato seed storage

The technique of diffused light storage of potatoes for seed use is based on the physiology of tubers. As has long been known, storage in natural diffused light instead of complete darkness will reduce sprout elongation, increase sprout numbers, reduce total storage losses, and allow a longer period of storage. This increases total yields because of improved seeding vigor and a greater quantity of seed potatoes. It can further increase farmers' incomes by allowing them to plant later or earlier and thus perhaps to harvest their crop during times of high prices. This system which has been promoted by CIP, is now being used extensively by farmers in Peru, Colombia, the Philippines, Sri Lanka and elsewhere. In surveys in these countries CIP identified 3000 farmers who were using this method of storage in 1984, but this surely is a considerable underestimate. The natural spread of this technology from farmer to farmer has been rapid in at least 16 countries including Colombia, Ecuador, Peru, Kenya, Tunisia, Sri Lanka, and the Philippines. This technique is also being used widely by government instrumentalities to improve their seed production programs.

The history of this innovation in its developing-country incarnation is instructive. It was preceded by 20 years of unproductive research on potato storage in Peru in which scientists tried to reduce shrivelling and rotting in storage. It was only because a social anthropologist from CIP asked farmers what their priority problems were that sprouting in storage was identified.

Moreover, shrivelling and rotting were not regarded by farmers as major problems. Scientists knew that diffused light reduced sprouting, and eureka, working with farmers as the innovators, in farm conditions, stores were built that used available materials and fitted in with traditional architecture, and now after a few years these practices have spread to at least 21 countries. All because someone asked the farmers, after 20 years!

The yield increase from using seed from diffused light storage in on-farm trials in the Peruvian highlands was from 8 to 20 percent. Trials in the Philippines and Colombia gave similar results. Yield increases were 57 percent in a trial on the Peruvian coast, and from 80 to 133 percent in Sri Lanka. On average, small-scale farmers in these countries store two tons of seed potatoes to plant one hectare. If the yields increase by 20 percent from, say, 10.5 t/ha, the increase in output would be 12,600 t of potatoes worth about $1 m. Adoption on 10 percent of potato area in the countries where CIP is actively promoting this technology, with the same assumptions about the base yield and increase, would result in over 1 Mt of additional potatoes, valued at about $100 m.

7.2.2 Seed potato technology

Programs to improve potato seed are being carried out in a number of collaborative programs between CIP and national research systems. The methods of improving seeds vary according to the local constraints. In Bangladesh, for example, it is mainly a matter of identifying when the insect vectors of diseases are serious and then identifying areas where seed potatoes can be grown to avoid infestation.

Methods were developed to improve the quality of the seed potatoes sown in the late crop in Tunisia. These methods consisted of: (a) desprouting imported seed and the earliest possible planting of the seed crop in the early season; (b) early harvesting of the seed crop and elimination of unhealthy tubers before storage; and (c) desprouting locally produced seed tubers before planting in the late season. Seed production increased from 64t in 1977 to 680t in 1980, and further to 880t in 1983. The higher quality seeds produced more main stems per plant. This doubled the yields per hectare in on-farm trials of the late season crop. An analysis of the program's total costs and benefits was conducted by CIP based on data from the national unit responsible for seed production with the results shown in Table 7.1. Unlike many seed potato efforts, this national project has continued to function effectively over an extended period.

Researchers in the national program in Rwanda (PNAP) followed a similar process of improvements. They selected and named in 1982 four late blight resistant varieties with yields of about 20 t/ha.

Rather than attempting to establish a sophisticated seed certification program, PNAP uses simple techniques to supply farmers with improved quality seed. Rwanda's seed production system is based on mass selection. Without post-harvest virus testing facilities, the system depends primarily on field observation of plant vigor and the proportions of healthy and diseased plants.

The seed program now produces about 250 t of seed per year of which about 200 t are distributed to seed multiplication projects throughout the country. PNAP does not multiply the older local varieties. About 50 percent

Table 7.1 Costs and benefits of the Tunisian seed potato program (000$)

	Program budget		Increased cost of seed	Total costs	Benefits	Net benefits
	International	National				
1976	90	24	0	114	0	-114
1977	90	24	7	121	36	- 85
1978	90	30	13	133	90	- 43
1979	90	30	26	146	182	36
1980	90	36	59	185	385	200
1981	35	42	85	162	544	382
1982	20	42	71	133	419	286
1983	0	54	66	120	502	382

Source: CIP, (1984)

of the seed produced and distributed is of new Rwandan varieties selected from genetic material introduced by CIP.

The result is an increasing number of Rwandan farmers with access to improved seed which gradually replaces old, degenerated materials. Production of improved seed is still significantly lower than current farmer demand for it. Yet, reports from seed projects and preliminary surveys indicate that about 7000 hectares, representing 18 percent of the total potato area, are now planted with seed originating from the national seed program. The average yield increase on farms due to use of improved seed is estimated at about 3 t/ha - a 40 percent increase over traditional seed.

An economic analysis indicates that, after a short start-up period, the seed multiplication program's benefits have far exceeded its costs. As of 1985, the internal rate of return of the program is projected to be 40 percent more than twice the return offered by most development projects in the country. Since the program is expected to continue operating at the same scale, the future rate of return is expected to be much higher. This is because costs will remain at about the same level while benefits increase significantly as cultivation of new varieties spreads. Giventhe slow virus degeneration rate, the multiplier effect of a small stock of clean seed is great.

7.2.3 Deep Vertisol technology

ICRISAT has developed a package of improved technological options for increasing output on deep Vertisols in some areas of semi-arid India. The package includes: (a) postharvest cultivation following the post-rainy season rabi crop; (b) land levelling and shaping, construction of field and

community drains and the use of graded broadbeds and furrows; (c) dry seeding before the monsoon: (d) use of modern cultivars and moderate amounts of fertilizer; (e) improved placement of seeds, and fertilizer; and (f) timely plant protection. Most of these practices are implemented with a bullock drawn wheeled tool carrier. This technology for deep (over 45 cm) Vertisol soils is called the broad bed and furrow system (BBF).

On four sites in three states, ICRISAT compared the new package with the traditional one in 1982-83. The new package cost about $70/ha more than the traditional technology and gave an average increase in profits of about $140/ha (Walker 1983). In 1982-83, ICRISAT measured the costs and returns of farmers' implementation of this package of practices against the local practices on about 50 ha in Maharashtra. Cost increases with the new package averaged $145/ha and profits increased about $50/ha compared to the traditional technology in that area, suggesting somewhat less advantage of the technology than in the ICRISAT tests.

The latter data may be taken as a conservative estimate of the unit impact of the technology because they are based on farmer trials, not those conducted by ICRISAT, and many farmers in India do not enjoy the same access as ICRISAT to needed inputs. The increase in profit is due partially to new varieties as well as the other components of the BBF technology which are the subject of the present chapter.

Some of the problems with the technology include the weight of the land levelling/shaping tool bar and the poor condition of bullocks at the time the work is needed, and inqualities in access to bullock draft power and credit to purchase the still-expensive equipment. It should be noted that the package

being tested deliberately does not include a weedicide, in order not to displace the opportunities for female weeders.

This system is being tested by national program researchers and extension workers in the states of Karnataka, Andhra Pradesh, Mahrashtra and Madhya Pradesh. In surveys taken at the on-farm verification sites, some farmers have indicated they will continue to use these technologies. The practice appears to have spread furthest in Karnataka and will spread more widely in the future in Karnataka, Madhya Pradesh and Maharashtra in a World Bank financed watershed development project. Observers in India estimated that, in 1983, it was being used on about 4000 ha of semi-arid rainfed land under the control of the respective state governments. This would have led to an increase in net profit of over $200,000 in 1983. The total area for which the technology seems well suited in India is estimated at 5 million ha. Increased productivity valued at $125m annually would be forthcoming if the technology were to be implemented on even half that area.

7.2.4 Blue-green algae/azolla technology

Azolla is an aquatic fern which grows in ponds, canals and rice paddies. Blue-green algae grow in cavities on the fronds of the fern and fix nitrogen from the atmosphere. The azolla can be used as a green manure in rice production to reduce the amount of manufactured nitrogen fertilizer used. Azolla technology has been long and widely used in Vietnam and China by rice farmers. IRRI helped to introduce azolla into the Philippines, and has also helped in the exchange of azolla germplasm among countries, including some azolla strains presently in use in Vietnam and China.

The best documented success of spreading azolla in S.E. Asia is in the Philippines. There IRRI, PCARRD and the Ministry of Agriculture had a cooperative project to test azolla in farmers' fields. It performed best in the irrigated areas of South Cotabato in Mindinao. The Ministry decided to publicize the value of azolla and distributed samples to a large number of farmers in 1980. By late 1981 it was being used on about 5000 ha of irrigated riceland in South Cotabato. A constraint to its adoption is the requirement for rather high levels of soil phosphorus and for relatively good water control and management, which means that prospects for its use in remote upland areas where fertilizer is most expensive are poor.

A small sample of the South Cotabato farmers was interviewed to determine the economic returns to azolla use in 1981 and 1982 (Kikuchi 1984). The major impact of azolla use was that farmers who incorporated azolla into their plots reduced their use of nitrogen fertilizer from about 40 to 25 kg/ha. There was no measurable change in yield. Some farmers also reported a decline in herbicide and hand weeding costs because azolla covers the surface of the water and supresses weeds. Evaluating these benefits at 1981 prices, the cost reduction ranged from $12 to 44 $/ha, more than 3 to 10 percent of the nonland cost of rice production. Thus, by 1981, those Philippine farmers had already saved between $60,000 and $220,000.

7.2.5 Crop intensification

The use of short-duration varieties and improved management practices has enabled certain regions to increase the intensity of cropping patterns. A good example is the case of Bangladesh wheat.

The national multiple cropping index increased from 1.45 to 1.54 in 1972/73, when semi-dwarf wheats were first introduced, to 1.54 in 1981-82 (Bangladesh Bureau of Statistics 1984). This coincided with the rapid adoption of semi-dwarf wheat varieties (Figure 7.1). The additional land planted to wheat resulted from increases in multiple cropping, not reductions from other crops. Between 1972/73 and 1981/82 the area of land single cropped in Bangladesh fell by 0.5 mil ha and the area double and triple cropped increased by 1.9 mil ha (Bangladesh Bureau of Statistics 1984). The area in other crops increased from 11.3 mil ha to 12.3 million ha, so there is no obvious indication that wheat substituted for other crops.

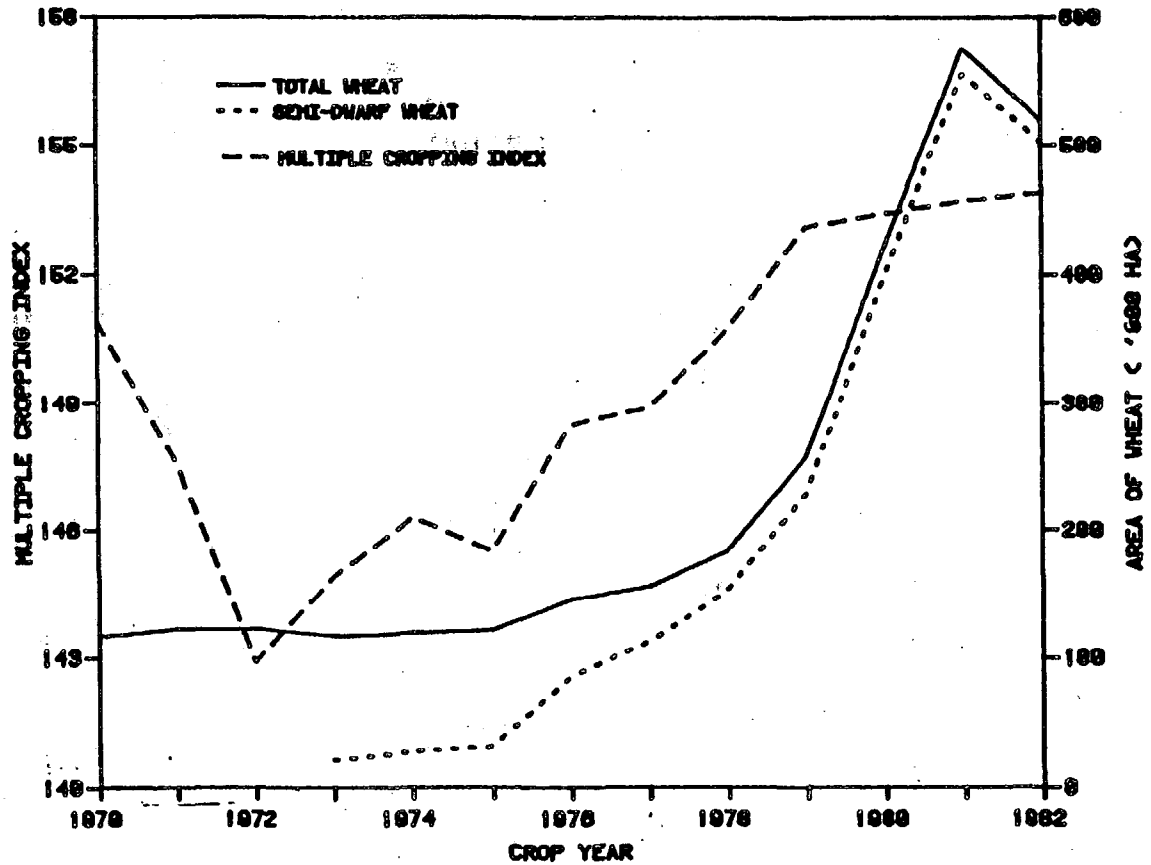
The increased food production from the added wheat land could be conservatively valued at $200m per year, with additional profits to farmers amounting to perhaps $40m per year.

IITA has developed many early maturing cowpea varieties. Some mature in only 60 days after planting. These varieties are an important key to intensified food production in rice-based cropping systems. Planted through rice stubble soon after the harvest of rice, the cowpeas grow on residual moisture as a catch-crop. They therefore permit two crops where only one was previously grown or three where two crops were grown before. This practice has already been adopted by a large number of small-scale rice farmers in the "fadamas" or wet valleys along the Kaduna and Niger rivers. This system is also being jointly tested in Asia by IITA and IRRI.

While there has been no worldwide survey to find the amount of intensification that has been due to varieties or management techniques developed by collaborative research between national research systems and the

Figure 7.1

MULTIPLE CROPPING INDEX, TOTAL WHEAT AREA AND AREA OF SEMI-DWARF WHEAT IN BANGLADESH, 1969-70 TO 1981-82



centers, there are a number of specific examples that can be cited. A major problem is to separate the intensification due to research from intensification due to population pressure or irrigation projects which had nothing to do with either international or national research. In the case of Bangladesh, irrigation for wheat increased, but over 60 percent of the new wheat area is grown without irrigation, on residual moisture and with sparse winter rains.

Several village level studies have linked new technology from farming systems research with intensification. Some examples are reported in Table 7.2. In a Javanese village "the introduction of double-cropping was facilitated by the diffusion of modern semi-dwarf varieties which mature early and are nonphoto-sensitive" (Hayami and Kikuchi 1982). Early maturing improved rice varieties in Nepal increased rice yields, allowed more optimal planting dates for the following crops(s) and made growing more crops per year possible (Van der Veen 1983). The deep Vertisol technology discussed in section 7.2.3 is a crop intensification strategy for the semi-arid tropics (Walker 1983).

Another fairly well documented case occurred in Iloilo province in the Philippines. The key techniques in this case were short-duration rice varieties, methods for direct seeding of the first rice crop and weed control using herbicides. These techniques allowed time for either two rice crops, or a rice crop and an upland crop to be grown where one rice crop had been the previous norm. The government Kabsaka project which is using these elements developed at IRRI had spread to 36,000 ha in Iloilo by 1984. Intensive research in several villages in the province found the system resulted in an increase in cropping intensity from 1.2 to 1.8, an increase in total rice

Table 7.2 Changes in cropping intensity associated with collaborative research

Location	Period	Multiple-cropping Index Start	Finish
	Rice Based Systems		
Bangladesh, National	1972/73 to 1981/82	1.45	1.54
North Subang village Java, Indonesia	1968/71 to 1978/79	1.50	2.00
Iloilo Outreach site Philippines	1974/75 to 1978/79	1.18	1.84
Dhobini village Nepal	1977/78 to 1980/81	1.59	1.68
	Semi-arid Tropics		
Taddanpally Watershed AP, India	1980/81 to 1982/83	1.06	1.39
Sultanpur Watershed AP, India	1981/82 to 1982/83	1.06	1.72
Farhatabad village Karnataka, India	1981/82 to 1982/83	1.29	1.67

yield of about 0.5 t/ha, and an increased income of between $140/ha and $500/ha; province-wide production increased by 18,000 t of rice and income by $5-18M.

7.2.6 Cassava drying technology

CIAT has been involved with Colombian farmers in the development of techniques for drying cassava so that it can be sold as cassava chips for animal feed. The process consists of chipping the cassava roots in a powered chipper modified from a machine used for the same purpose in Thailand, and spreading the cassava chips on a flat concrete surface to dry under the sun for 2-3 days. The chips must be turned six or eight times each day to ensure uniform drying; drying is terminated when the moisture content of the chips is about 14 percent.

This process was introduced to the north coast of Colombia in 1980. This area is dry and infertile, and only cassava and a few other crops grow well. CIAT worked with a small producers' cooperative which was also receiving assistance from an integrated rural development program. By 1982, the cooperative had expanded and was operating on a semi-commercial basis. It sold all 39 tons produced to a feed company in Cartenga. By 1983, this plant had expanded output to 270 tons and in 1984 there were seven plants in operation with 20 more being established in N.E. Brazil, Mexico and Panama.

7.2.7 Cassava management

The Cubans have extensively adopted the "Colombian" system of cassava production by adapting CIAT recommendations, in some cases using research methods learned at CIAT, to Cuban conditions. They selected the best local varieties and then taught agronomists from the state agricultural enterprises

the new management methods. These included: (a) good soil preparation with construction of ridges taller than those used for sugarcane; (b) selection and treatment of 30 cm stakes from the basal part of mature plants, to reduce the problem of cassava bacterial blight; (c) planting vertically on top of the ridges; (d) timely weed control; and (e) reduced irrigation. Before the training, Cuban farmers had planted short stakes horizontally on the bottom of small ridges and irrigated heavily.

Cuban cassava production increased from 24 kt in 1974-76 to 330 kt in 1981-83 (FAO). CIAT estimated that 10,000 of the 50,000 total ha used the "Colombian" system. Evidence from the Cuban Minister of Agriculture is that yields increased from 7 to 20 t/ha on the state farms. Assuming that the area using the new methods included at least 10,000 ha of state farm lands, the increase in output is 130 kt of cassava valued at about $4M.

7.2.8 IRRI mechanical innovations

The range of center-related agricultural machines is surveyed in chapter 18, and those associated with IRRI in particular in section 18.4. They are mentioned here in the context of output effects realized from research findings other than related to plant breeding because they have doubtless had some significant effects in reducing costs and thus encouraging increases of output albeit with some displacement of labor, as reviewed in the more general discussion of mechanization of chapter 8.

Consider initially the case of improved rice threshers. Farmers adopt those variously: (a) to reduce the cost of threshing, (b) to save turnaround time so that subsequent crops can be planted earlier and (c) to reduce crop losses in threshing. The empirical evidence indicates that, in the

Philippines where the threshers are replacing hand beating or foot treading, there is virtually no reduction in the cost of threshing a ton of rice but substantial reductions in producers' losses in threshing. In Thailand, the previous method was animal or tractor treading. Studies in Thailand show there are slightly greater grain losses with the IRRI threshers but there was a substantial reduction in the cost of threshing. There is no evidence that mechanical threshing reduces turnaround time.

Whatever the source of economic gains, the monetary net benefits of using the threshers are considerable and range from about $30-80/yr for portable machines in the Philippines and Thailand to $400/yr for large machines in the Philippines.

7.2.9 Land clearing and management technology

One way to increase food production in the humid and subhumid tropics is to bring forest land under cultivation. But such new land development projects must be carefully planned and executed, otherwise lush tropical forests turn into barren lands in a relatively short period. IITA's farming systems scientists have, for over ten years, investigated various methods of clearing tropical forests and the effects of these methods on subsequent crop production. These studies have led to the development of a package of recommendations for land clearing and soil management.

Land clearing should be done in a way that minimizes soil disturbance; thus, wherever possible heavy machinery should not be used. A mechanized clearing operation should not remove the litter, roots or stumps nor scrape off the top soil, should not compact the subsoil nor drag trees or stumps over long distances. Following clearing, residue mulch should be maintained on the

soil surface and mechanical tillage should be kept to an absolute minimum, for soil distrubance and its exposure to intense tropical rains are the causes of soil erosion. IITA has promoted this technology through publications, conferences and workshops.

This land clearing and management technology has been adopted by the Sumatra-Indonesia Transmigration Schemes, the World Bank-funded agricultural development projects (ADPs) in Nigeria, Ivory Coast, and Cameroon, land development projects in N. Thailand and in Yurimaguas, Peru.

7.2.10 Plant protection

The major plant protection technology advanced by the centers has been the production of pest-resistant varieties or making pest-resistant germplasm available to national systems. In addition, the centers have developed other means of reducing the ravages of pests and diseases through biological control and integrated pest management.

Centers have screened insecticides, herbicides and fungicides for their effectiveness against pests. This screening is used by governments and farmers to help to determine which chemicals should be used. The testing has undoubtedly saved money by providing governments with information that has helped them to avoid inappropriate chemicals. IRRI research on the role of insecticides in the resurgence of brown planthopper led the Philippine government to take methyl parathion off the list of approved pesticides that were supplied at subsidized rates.

Center research has also hastened the acceptance of certain weed-control measures. Thiobencarb, a herbicide tested by IRRI, is now used in 55 rice-

growing countries. Butachlor, also tested by IRRI, is now marketed in 22 countries. Informal discussions with officials from chemical companies revealed the opinion that IRRI tests had accelerated the initial acceptance and spread of new herbicides by several years.

IITA's biological control project on cassava green spider mite and cassava mealybug is a major biological control effort. Cassava green spider mites were first reported in Uganda in 1971, and the cassava mealybug was identified by an IITA research team in Zaire in 1973. It is assumed that these pests were introduced accidentally from Latin America. Their spread has been rapid and they are now found in over 60 percent of the cassava growing areas of Africa, in a wide belt of Mozambique in the east through Zaire and the Central African Republic, across the coastal regions of W. Africa to Senegal and Guinea Bissau. It has been estimated that these two pests cause economic losses of nearly $2 billion yearly in Africa.

IITA has addressed these pests in two ways. First, there is the conventional breeding program in which sources of resistance to the two pests have been identified and are being incorporated into cassava breeding lines. Also, attempts are directed towards using both cultivated and other Manihot species in the development of higher levels of resistance.

The second approach, biological control, introduces host-specific natural enemies from the pests' area of origin in S. America as a means of effectively reducing pest populations to the tolerable levels that exist on that continent. CIAT collaborates in the search for natural enemies in S. America.

From November 1981 to the end of 1984, approximately 50,000 of the cassava mealybug's natural enemy Epidinocarsis (Apoanagyrus) Lopezi were released in 10 African countries: Congo, Gambia, Ghana, Guinea-Bissau, Nigeria, Rwanda, Senegal, Togo, Zaire, and Zambia. The establishment of E. Lopezi - a wasp that parasitizes the mealybug - has been recorded in eight of the countries. A natural enemy is considered established when it has survived a full rainy season, the period of low mealybug population, and has been located again 12 months after release.

A significant reduction in the number of cassava mealybugs to below the injury level has been observed in every zone colonized by E. Lopezi. In those zones, the mealybug now reaches peak population densities of only 10 to 20 per terminal cassava shoot and often less than this number, compared with a peak population of more than 1,500 per shoot before the introduction of the wasp.

New attempts are being made to find additional effective natural enemy species. A complex of species would be more desirable to assure a permanent and reliable suppression of the mealybug.

7.3 Coda

* It is more difficult to develop estimates of the impact of management technology than of germplasm technology and the problems of attribution are more complex.

* Programs to improve potato seed are being carried out in a number of CIP-

national research system collaborative programs. The technique of diffused light storage reduces sprout elongation, increases sprout numbers, reduces total storage losses, and allows a longer period of storage. This system is now being used extensively by farmers in Peru, Colombia, the Philippines, Sri Lanka and elsewhere.

* ICRISAT has developed a package of improved technological options for increasing output on deep Vertisols in the wetter areas of semi-arid India. This system is being used on about 4000 ha in on-farm tests by national program researchers and extension workers in the states of Karnataka, Andhra Pradesh, Mahrashtra and Madhya Pradesh.

* IRRI has helped to introduce the biological nitrogen fixing system using azolla into the Philippines, and has helped in the exchange of azolla germplasm among countries. One study in the Philippines found that farmers who incorporated azolla into their plots reduced their use of nitrogen fertilizer from 42 to 24 kg/ha, without reducing yields.

* The use of short duration varieties and improved management practices has enabled certain regions to increase the intensity of cropping patterns. The classic case is Bangladesh wheat affecting 0.5 million hectares; the deep Vertisol technology is also a crop intensification strategy.

* CIAT has assisted Colombians in the development of techniques for drying cassava so that it can be sold as cassava chips for animal feed. By 1983, there were seven plants in operation in Colombia, with 20 more being established in northeast Brazil, Mexico and Panama.

* Cuban farmers have extensively adopted the "Colombian" system of cassava production which consists of adapting CIAT recommendations.

* The monetary net benefits of using the IRRI threshers range from about $30—80/yr for portable machines in the Philippines and Thailand to $400/yr for large machines in the Philippines.

* The major plant protection technology advanced by the centers has been the production of pest resistant varieties or making pest-resistant germplasm available to national systems.

* IITA has introduced biological control of major cassava pests to severely affected producing areas in 10 African countries and significant reductions in pest population have been observed.

8 DISTRIBUTIONAL AND NUTRITIONAL IMPACTS OF CENTER-RELATED VARIETIES

8 DISTRIBUTIONAL AND NUTRITIONAL IMPACTS OF CENTER-RELATED VARIETIES

8.1 Introduction

In this chapter the influence of modern crop varieties 'in the large' on income distribution and nutritional status, especially among the most impoverished groups is addressed. Many new varieties can be associated more-or-less easily with crop improvement activities of the centers, but in this review no attempt is made to distinguish between the contribution of the individual centers and of the other key factors in the production of modern varieties. Much of the chapter is based on a study paper prepared by Michael Lipton with the assistance of Richard Longhurst (Lipton and Longhurst 1985).

8.2 How Modern Varieties of Food Staples Affect the Poor

After 20 years of experience with the modern varieties, the effects on the poor surely should be known. This chapter is intended to reassess the vast research literature on this topic in a way that may lead to the setting of a revised agenda for enquiry and action, by the centers and others, to improve the poverty-reducing impact of modern varieties.

The 20 years since the first introduction of modern varieties have been perceived by social scientists more or less in four quinquennia:

(a) In 1966-70, the "miracle seeds" were to solve the food consumption and production problems of rich and poor alike (e.g., Brown 1970).

(b) In 1971-75, the "green revolution" allegedly enriched the rich but impoverished the poor, thus threatening or promising to turn red (e.g., Frankel 1971, Borgstrom 1974).

(c) In 1976-80, consensus grew that modern varieties helped many of the poor (except farmers in neglected areas), but less than the rich. Small-scale farmers, though adopting late, attained good yields. Hired employment increased, but seldom wage-rates. Above all, as modern varieties increased food supply, they kept food prices to poor consumers down.

(d) In 1981-85, there are claims that modern varieties often raise poor people's levels of living faster than rich people's, even if the institutions of land tenure, rural credit, etc. are wrong. If poor farmers lose land, if rich farmers replace workers by threshers, modern varieties are largely guiltless (Barker and Herdt 1985, Hayami 1981).

Is it merely research fashions that are changing? Is the farm reality changing, as poor farmers catch up with the leaders in use of modern varieties? Or are the latest modern varieties themselves different from early ones,

perhaps more "poor-friendly", as breeders aim more at drought and pest resistance (Herdt and Capule 1983) and at poor people's crops like sorghum?

Past scientific research has sought modern varieties helpful to the poor by using more labor, supplying cheap food energy, etc. Socio-economic research has documented these effects on the poor, which are real and good. But, in the total context, most of Africa is without modern varieties and is poorer than in 1970, and the incidence and severity of poverty in S. Asia are little changed despite modern varieties. Diagnosis of means to alleviate poverty in these situations increasingly needs to start from the reality of members of typical poor households who may well simultaneously be "small-scale farmers", "employees" and "off-farm food consumers".

A research agenda for social scientists concerned with development will probably move gradually from the economics of particular farm practices and adoption decisions of specified groups of farmers to the socio-economics of poor people's total positions. This might involve, for example, asking how and why the well-being of the poorest, say, fifth of the population in modern-variety areas, in other farm areas, and in cities, changes in the wake of modern varieties. Analogously, the agenda may move from analyzing, after the event, particular effects of modern varieties on particular groups of poor people, toward recognizing the overriding effect of resource ownership on income distribution, and the limited role that the design of new modern varieties and recommended practices can have in determining the welfare of the poor, aside from reducing the costs of food consumption. Some of these issues are returned to in section 8.4.5.

8.3 Physical Features of Modern Varieties: Impact on the Poor

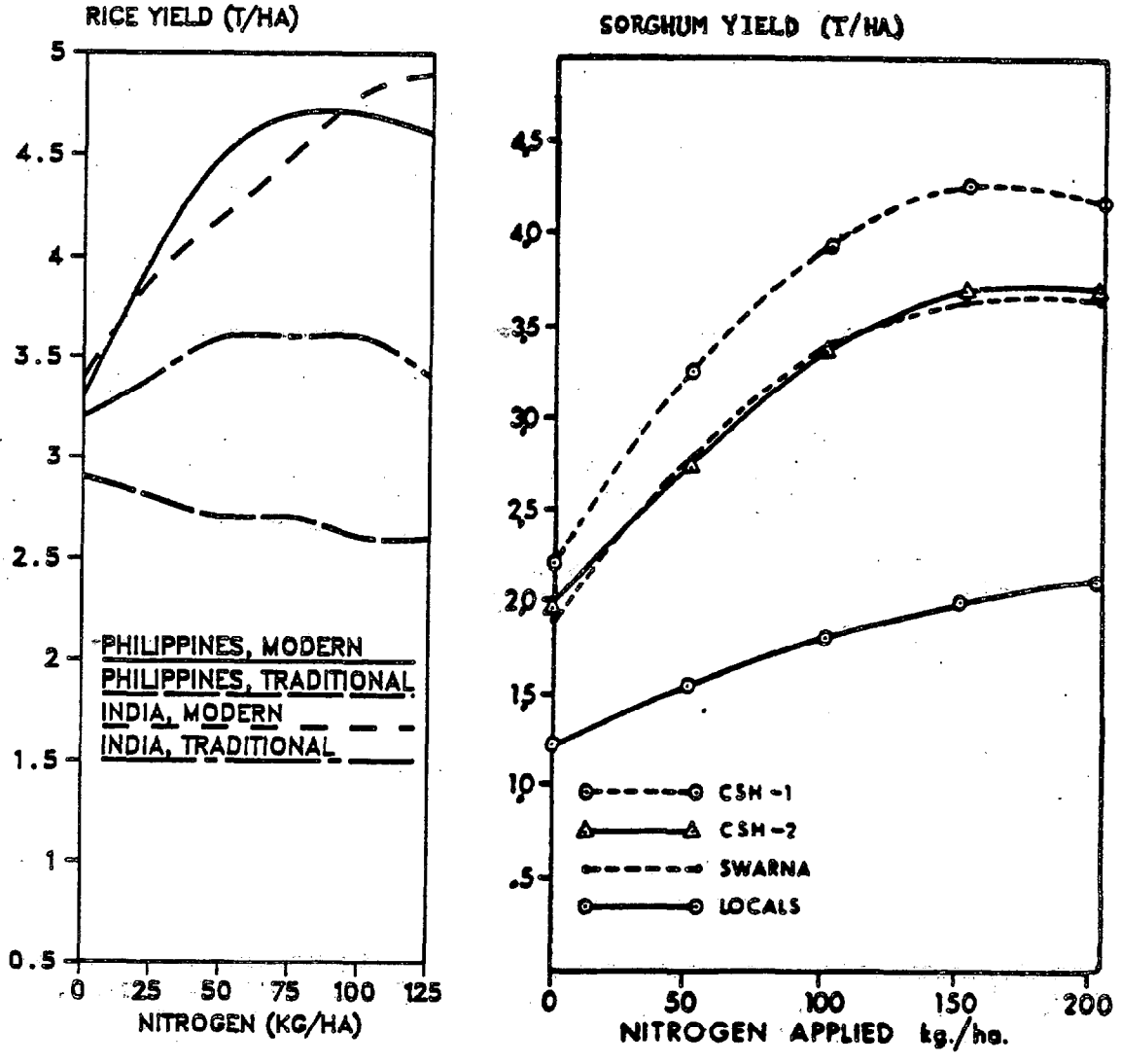
8.3.1 Soil nutrient response

Many critics claim that, if the poor cannot afford fertilizer, they lose by switching to modern varieties because these then yield less than traditional varieties. This claim is wrong. Modern varieties are indeed designed to yield much more at high levels of the macro soil nutrients, nitrogen, phosphorus and potassium (N, P, K, respectively) from all sources, e.g., by not lodging (dwarf and semi-dwarf modern varieties) or by hybrid vigor. But such design aims to convert NPK more efficiently into grain weight, and so most modern varieties outyield traditional varieties even with no fertilizer (IRRI 1975, pp.19-21, Kahlon 1974, p.5), especially as denser plantings then tend to mean fewer weeds. This is illustrated in Figure 8.1 for rice and sorghum. A number of experiments comparing modern with traditional rices and modern with traditional sorghums were compiled. The individual experiments as well as these averages show that modern varieties have both higher response to applied nitrogen, and higher yield at zero applied nitrogen. As newer modern varieties are bred to resist pests and diseases, their advantage over traditional varieties at zero fertilizer has increased (Byerlee and Harrington 1982), even under moisture stress (Barlow et al. 1983, Rao 1982). Still, there are worries for the poor.

First, modern varieties must get the extra nutrients, mainly N, P and K, needed for higher yields, from somewhere. At zero fertilization, this risks "soil mining" although many soils have sufficient available P and K to last for decades, even at high extraction rates. The centres and their partners should

FIGURE 8.1

YIELD RESPONSE OF RICE TO APPLIED NITROGEN ON 30 EXPERIMENTS IN THE PHILIPPINES AND 18 EXPERIMENTS IN INDIA (BARKER AND HERDT, 1985) AND YIELD RESPONSE OF SORGHUM TO APPLIED NITROGEN ON 25 EXPERIMENTS IN INDIA (SINGH, KRANTZ AND BAIRD, 1970)



perhaps look more beyond single-season fertilizer responses, and should design, for poor farmers, modern varieties and total nutrient policies to preserve long-run soil-food security. Second, a few aberrant modern varieties perform worse than traditional varieties with low or zero fertilizer. Third, the moderate yield advantages of most modern varieties at zero fertilization can be outweighed by price discounts below traditional varieties, and/or lower straw yield. Fourth, modern varieties bred for maximal grain/N ratios: (a) often reduce straw for fodder and thatching, (b) may require P or perhaps micronutrients such as zinc (Zn) purchases to achieve high yields, (c) may store badly due to thin husks, (d) may have higher seed costs, at least initially, or (e) may sometimes show larger yield loss under moisture stress. Handling these complexities requires purchases, information and risk-taking that may not be easy for poor, illiterate farmers. The result may be that they refrain from adopting when it may be in their own self interest to adopt. So, if these rather than laborers, or urban consumers are the main poverty group, center and other researchers need modern varieties, rotations and practices that are very soil-nutrient efficient, even under moisture stress, and even perhaps at some cost to yield potential. Poor people's crops especially (millets, sorghum, cassava), are often grown unfertilized on fragile soils, so efficiency of response to soil macro nutrients at low levels is critical.

8.3.2 Light response

Direct breeding for greater photosynthetic efficiency (via erect leaves) and reapportioning photosynthate between stem and grain was a major goal of the centers during the 1960s. Having achieved that for wheat and rice, it cannot

in the future be a major source of incremental gain as it was then. Indirectly, modern varieties with low photo-period sensitivity remain a major research goal. They thrive irrespective of the pattern of day-length, provided that total light, water and nutrients suffice. Often this permits double cropping and more even flows of food through the year (Bolton and Zandstra 1981); the poor gain most, since they can seldom save or borrow against lean seasons. But local specificity, not broad adaptability, is sometimes needed; for example, where plants should mature in the late rains to permit sun-drying, those who cannot afford mechanical drying methods may want high sensitivity to daylength in order to synchronize the flowering and maturity of the crop with the climatic environment (Beachell et al. 1972).

Many poor farmers, therefore, want high photo-period sensitivity at harvest time, but low sensitivity earlier. Center researchers, for example, may brilliantly seek out modern varieties and practices with criteria that the research community think are important. On photo-period sensitivity and other attributes, however, they may need to do more to be responsive to the "felt needs" and actual payoffs of their poorer clients before settling on criteria to guide their work.

8.3.3 Water response

Modern varieties have been criticized as raising yields only through use of more water, and as being more drought-prone than traditional varieties (Borgstrom 1974, Griffin 1975, p.205). Actually most modern varieties are bred for root structures that give better returns per unit of water, especially (but

not only) where accompanied by higher nitrogen inputs (Borlaug 1972, Swaminathan 1974). But this very fact raises the payoff to farmers from getting more or timelier water -- perhaps at the expense of poor, weak, or tail-end users. Fortunately, modern rice varieties increasingly resist moisture stress better than traditional varieties, reflecting in part one of IRRI's main objectives since 1971 (IRRI 1972, p.85). Barley, millets and sorghums are similarly bred for vigorous root system. Hybrid sorghum has raised farmers' yields greatly in drought-prone areas of India (Rao 1982, pp.49-50). Wheat producers in Pakistan and Tunisia and rice producers in the Philippines and Bangladesh, without irrigation, have often adopted modern varieties mainly for drought resistance, not for good-season high yields (Barker 1972, Palmer 1972, Rochin 1973, Herdt and Capule 1983).

Most of the poorest people live in vast areas of unreliably rainfed rice, or of semi-arid crops. ICRISAT and ICARDA are concentrating their full attention on the latter-such areas and the other centers are also now devoting substantial resources to rainfed agriculture, but most of these areas remain in traditional varieties. Why? (a) The politics of non-farmer controlled irrigation leave many farmers with inadequate, untimely water, so that the gains from switching to modern varieties are small. (b) Some research stations, such as IRRI headquarters, are located in well-watered regions and thus perhaps ill-equipped readily to analyze moisture stress, despite major outlays and field studies. (c) For semi-arid crops in Africa (and in Asia in winter) and for upland rice, the centers have not yet radically improved water use efficiency: their biological approaches (perhaps modified towards robust

intermediate-yielding varieties like H4 and C4-63 rice) may need to be integrated further with ecological engineering to, say, reduce evaporation, seepage and run-off, before farmers can gain the needed benefits. ICARDA's findings of improved water-use efficiency and earlier maturity of barley under phosphorus application offer scope for improvement in its mandate areas, especially if some governments' restrictions on use of P are lifted.

More research in water-insecure areas (and less on irrigated crops) means more income for some of the world's poorest farmers but may mean lower total returns, to research investment, and thus less, or costlier, food for the poorest consumers (Brass 1984). This apparent dilemma can be resolved only by major improvements to the water security of unirrigated farmland. These have become less fashionable with international donors and national governments due to the failure of irrigation "white elephants", and attempts to transform farmers' water use systems (e.g., by advising early planting) without understanding their constraints. Modern varieties linked to selective, farmer-controlled micro-irrigation (or micro-drainage) may be the only route to affordable, efficient increases in water-grain conversion rates in dry (or flood-prone) areas.

8.3.4 Stability against diseases, pests and weeds

The critics' claims of greater susceptibility (Griffin 1975, p.205, Palmer 1972, p.23, Whitcombe 1973, p.199), if true, would hit hardest at the poorest, who lack information and, in time of need, lack pesticides too. Some early modern varieties such as TN-1 and IR8 were indeed "insect pest museums" but

later ones possessed better resistance; IR20 rice lasted 10 years, Sonalika wheat 20. Currently, yield increases are bought mainly by raising robustness, not by sacrificing it to yield potential. The centers have also helped national breeders to respond quickly, e.g., to the successive brown plant hopper biotypes which emerged in Indonesia.

The centers' work seemingly has, however, understressed one of poor farmers' most damaging pest problems. Weed research seemingly: receives few resources (relative to weed damage); concentrates them on testing commercial weedicides (perhaps tending to displace poor workers rather than raising yields) (e.g., CIMMYT 1983, pp.89-91); and sometimes is rather unspecific about how to help in fighting which weeds, in which crop (let alone which farm system) when, where and with what costs and benefits. Weeds can be very damaging in dry areas where they compete for scarce soil moisture (mainly women's labor for control, and accordingly are receiving some attention at ICARDA. Rats and bird pests also seem grossly neglected by the centers, in view of the relative damage they do in technology-poor Africa (Jones 1982, p.720, ICRISAT 1983, pp. 4, 83, IRRI 1983).

The narrow genetic base of modern varieties is a danger being tackled by the centers (chapter 12), and fears that the poor are threatened have been exaggerated (Mooney 1979). The centers have unprecedented, freely accessible germplasm collections, and have used wild races when traditional varieties, too, prove vulnerable (cf. the use of O.sativa genes against grassy stunt in rice). Breeding for yield is seldom anti-poor and may be pro-poor. Dense

modern-variety stands hinder weed growth. Fertilizers can also help but may increase resistance to tungro in rice and alternaria in wheat. Irrigation should not increase disease (Saari and Wilcoxson 1974, p.50) but modern-variety induced double-cropping, especially of the same crop, gives pests year-round homes (IRRI 1973, p.74). Generally, modern-variety research has enormously reduced disease and pest risks faced by growers. This helps the poor most. Their risks remain great, however, if with reduced genetic diversity, national research systems cannot respond quickly with resistant materials (as Indonesia with the assistance of IRRI did when IR36 proved vulnerable to biotype 3 of the brown plant hopper).

Modern varieties enhance yields via short stalks, erect leaves and dense roots. These, respectively, improve efficiency of use of nutrients, light and water, and therefore the capacity to tolerate shortfalls or mis-timing of them. The better modern varieties are also being made more tolerant of pest and disease attack. The social and economic systems into which they are introduced, however, often thwart, or even reverse, the pro-poor effects of all this.

8.4 Modern Varieties and Distribution of Benefits among Farmers

Initial research on the relationship between farm size and adoption showed that large-scale farmers adopted new varieties sooner than small-scale farmers. This has led to the wide misperception that small-scale farmers are non-adopters, but the great mass of evidence shows that, where modern

varieties are suited to the edapho-climatic conditions, they have been adopted by roughly the same proportion of farmers in all farm size groups. This is illustrated in Figure 8.2 for several sets of data on Asian rice producers.

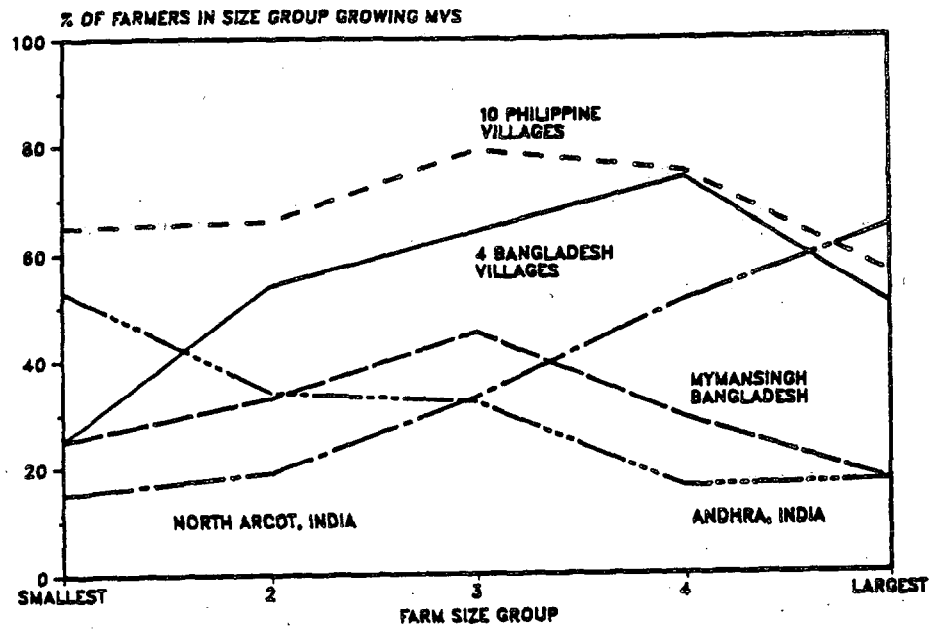
A broadly-based examination of a significant Asian example of the relationship between farm size and use of modern varieties is possible from data for the mid-1970s collected in a nationwide study by the National Council of Applied Economic Research of India. Data from three representative states are plotted in Figure 8.3 The percentage of crop area planted to modern varieties was computed for each of five categories of farm size, namely: <1, 1-2, 2-4, 4-10, >10 ha).

In some states, such as Madhya Pradesh, most of the land was planted to traditional varieties while in others, such as Haryana, most was planted to modern varieties. No positive association is apparent between farm size and percentage of area in modern varieties and, in cases such as Uttar Pradesh there is, if anything, an inverse relationship. It is also revealed that, while the modern varieties are largely irrigated, there were also signficant areas of traditional varieties that were irrigated at the time the study was conducted.

8.4.1 Adoption, farm size, tenure and risk

Research on relationships between size, adoption and yield does disclose something about how modern varieties affect the poor -- although perhaps more about the prospects in particular rural societies of coherence and stability,

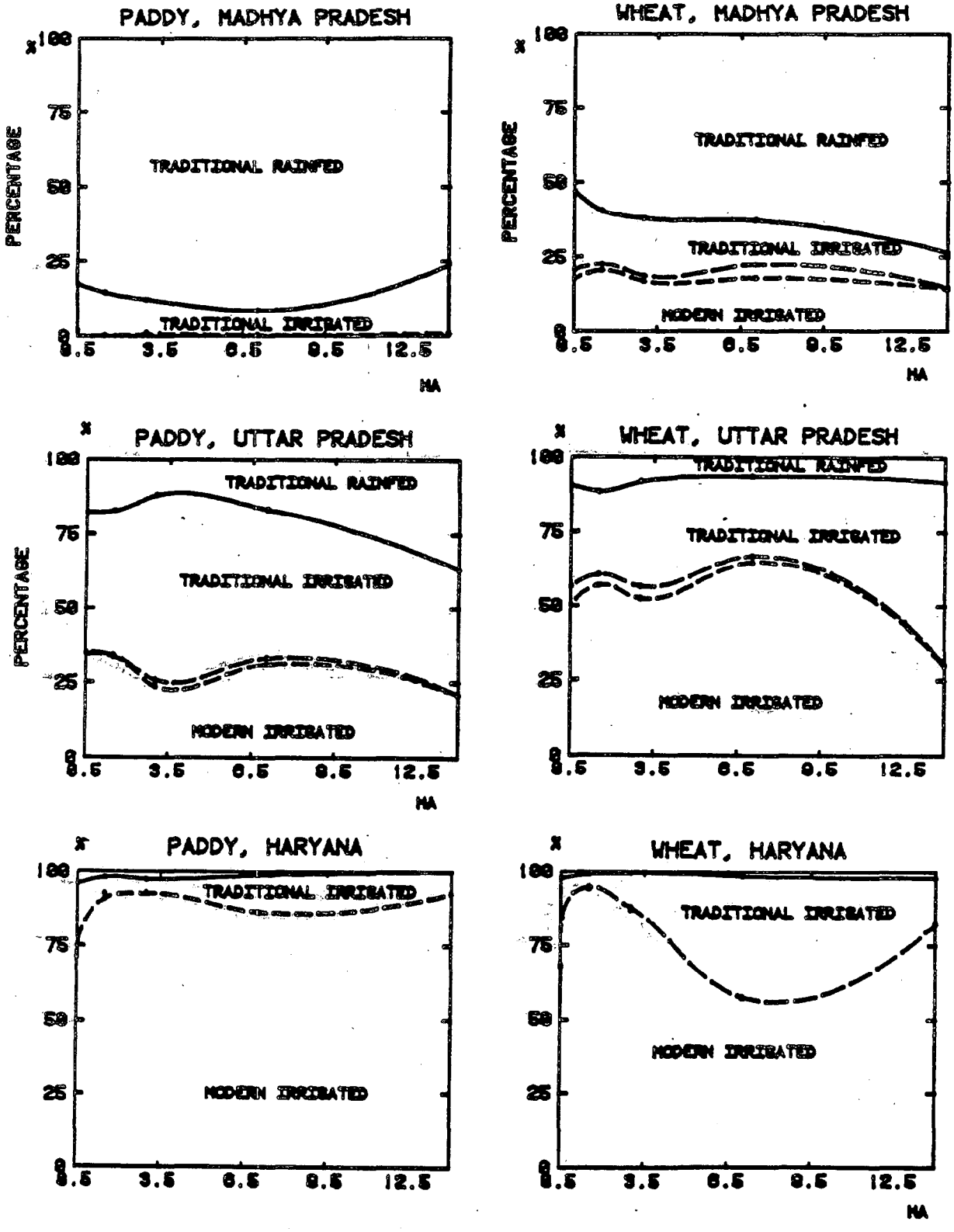
FIGURE 8.2



SOURCE: HERDT AND CAPULE 1983 AND MUTHIAH 1971

FIGURE 8.3

PERCENTAGE OF LAND IN FARMS OF DIFFERENT SIZE GROUPS PLANTED TO MODERN AND TRADITIONAL RICE AND WHEAT VARIETIES IN SELECTED STATES OF INDIA, 1975-76.



insofar as these depend on the spread of scientific farming beyond large-scale farmers. Early studies clearly showed that large-scale farmers were indeed adopting modern varieties relatively quickly (Lockwood et al. 1971, Schluter 1971, Herdt and Capule 1983, p.3). Later work showed that small-scale farmers were catching up (Dasgupta 1977, pp.227-8, Byerlee and Harrington 1982, p.3, Barker and Herdt 1984, pp.24-33), often leaving the bigger ones, however, with "innovators' rents". This catch-up is not happening everywhere (Herdt and Garcia 1982) and is by no means automatic.

Unfortunately, not all modern varieties are smallholder-friendly and smallholders, although adopting readily in the right circumstances, are more often located in the wrong ones (no irrigation, bad topography, no extension) than richer farmers (Cutie 1975, Colmenares 1975). In Mexico, poor ejidatarios (communal farmers) more readily than small private farmers could restructure their assets so as to benefit from modern varieties (Burke 1979). Owner-farmers do not adopt more than tenants unless as often happens, tenants get more costly credit per hectare.

Because they avoid risk until they have seen their wealthier neighbors succeed with modern varieties small-scale farmers may adopt later; or because they cannot get scarce inputs at first they may delay adoption. Credit appears more constraining in irrigated areas, risk elsewhere (Schluter 1974, Anderson and Hamal 1983). Risk may deter adoption only where the techology has fixed cost (Feder and O'Mara 1981, pp.60-1). This theory is supported by studies suggesting that, where smallholders adopt later, they sow a bigger proportion

of land to modern varieties than do larger scale farmers so as not to spread their fixed costs over too small an area (Dasgupta 1977, pp.229-32, Asaduzzaman 1980, Herdt and Garcia 1982).

8.4.2 Inputs and incentives to support modern varieties

Are modern varieties normally, or causally, linked with labor-displacing inputs, which favor bigger farms with more savings and less family labor per hectare? Rice modern varieties indeed were strongly linked to herbicides, tractors and threshers in tightly-scheduled double-cropping areas such as the Philippines, Malaysia, W. Java (Barker and Herdt 1978, pp.85, 87, cf. Gibbons et al. n.d., p.221, Lingard and Baygo 1983). In some of these locations the development of short duration varieties made double cropping possible. Even shorter duration varieties, presumably with some sacrifice in yields, could help to spare smaller farms and landless laborers from the effects of threshers and tractors.

Do modern varieties generally yield better for big farms because they effectively utilize more inputs? Richer farmers are better able to afford timely fertilizers and to seize timely tubewell water (Dasgupta 1977, pp.91-2, Smith et al. 1983). But can selected modern varieties help small farmers to substitute manure, or labor-intensive methods of applying water or fertilizer for more input purchases? In the longer term, modern varieties tend to receive similarly high levels of inputs on small and large farms. But institutions allocating water, fertilizers, or credit tend to be biased toward large farms, especially those owned by men. If the biases cannot be corrected and if the

insofar as these depend on the spread of scientific farming beyond large-scale farmers. Early studies clearly showed that large-scale farmers were indeed adopting modern varieties relatively quickly (Lockwood et al. 1971, Schluter 1971, Herdt and Capule 1983, p.3). Later work showed that small-scale farmers were catching up (Dasgupta 1977, pp.227-8, Byerlee and Harrington 1982, p.3, Barker and Herdt 1984, pp.24-33), often leaving the bigger ones, however, with "innovators' rents". This catch-up is not happening everywhere (Herdt and Garcia 1982) and is by no means automatic.

Unfortunately, not all modern varieties are smallholder-friendly and smallholders, although adopting readily in the right circumstances, are more often located in the wrong ones (no irrigation, bad topography, no extension) than richer farmers (Cutie 1975, Colmenares 1975). In Mexico, poor ejidatarios (communal farmers) more readily than small private farmers could restructure their assets so as to benefit from modern varieties (Burke 1979). Owner-farmers do not adopt more than tenants unless as often happens, tenants get more costly credit per hectare.

Because they avoid risk until they have seen their wealthier neighbors succeed with modern varieties small-scale farmers may adopt later; or because they cannot get scarce inputs at first they may delay adoption. Credit appears more constraining in irrigated areas, risk elsewhere (Schluter 1974, Anderson and Hamal 1983). Risk may deter adoption only where the techology has fixed cost (Feder and O'Mara 1981, pp.60-1). This theory is supported by studies suggesting that, where smallholders adopt later, they sow a bigger proportion

of land to modern varieties than do larger scale farmers so as not to spread their fixed costs over too small an area (Dasgupta 1977, pp.229-32, Asaduzzaman 1980, Herdt and Garcia 1982).

8.4.2 Inputs and incentives to support modern varieties

Are modern varieties normally, or causally, linked with labor-displacing inputs, which favor bigger farms with more savings and less family labor per hectare? Rice modern varieties indeed were strongly linked to herbicides, tractors and threshers in tightly-scheduled double-cropping areas such as the Philippines, Malaysia, W. Java (Barker and Herdt 1978, pp.85, 87, cf. Gibbons et al. n.d., p.221, Lingard and Baygo 1983). In some of these locations the development of short duration varieties made double cropping possible. Even shorter duration varieties, presumably with some sacrifice in yields, could help to spare smaller farms and landless laborers from the effects of threshers and tractors.

Do modern varieties generally yield better for big farms because they effectively utilize more inputs? Richer farmers are better able to afford timely fertilizers and to seize timely tubewell water (Dasgupta 1977, pp.91-2, Smith et al. 1983). But can selected modern varieties help small farmers to substitute manure, or labor-intensive methods of applying water or fertilizer for more input purchases? In the longer term, modern varieties tend to receive similarly high levels of inputs on small and large farms. But institutions allocating water, fertilizers, or credit tend to be biased toward large farms, especially those owned by men. If the biases cannot be corrected and if the

research system is to be friendly to the poor, technologies should be selected to help smaller scale operators to overcome such biases.

Later adopters, usually the poor, often receive output prices reduced by the effects on supply of the early adoption by their better-off neighbors. Richer farmers may also get better prices than the poor via scale-economies in marketing or timelier sales, and modern varieties seem to increase these advantages (Swenson 1973, pp.77-8. 113, 1976, p.3). Resource-poor farmers may, however, avoid such disadvantage by eating most of their additional modern-variety output (Cordova et al. 1981, Deuster 1982).

8.4.3 Farm size, yield, efficiency and modern varieties

Small-scale farmers ultimately adopt as much and as intensively as others. Having more family labor per hectare, they usually get higher yields. A few data suggest that modern varieties reverse the traditional "inverse relationship" of smaller farms to higher yields (Roy 1981, Bhalla and Chandha 1983, pp.62-73). Small farms are, however, usually protected in their yield advantage by several factors. After full adoption, they get the benefit of greater cropping intensity and crop value. At an earlier stage, slightly lower yields per season on smaller farms, with lower purchased inputs per hectare, may be privately and socially efficient, but as they progress fully to modern varieties, the traditional "inverse relationship" reappears (Chattopadhyay and Rudra 1976, ps A-109, A-117, Byerlee and Harrington 1982, p.3).

In Bangladesh, about 12 percent of farmers 1 ha and below are growing semi-dwarf rice varieties while a slightly smaller proportion of farmers with over 1 ha is growing them (Figure 8.4). The highest proportions of fertilizer users are in the three smallest farm size groups, and the use of irrigation closely parallels the adoption of semi-dwarf rices. Thus, even in Bangladesh, which ranks second to Chad in the World Bank's poverty list, small-scale farmers are alert to the possibilities offered by new technology.

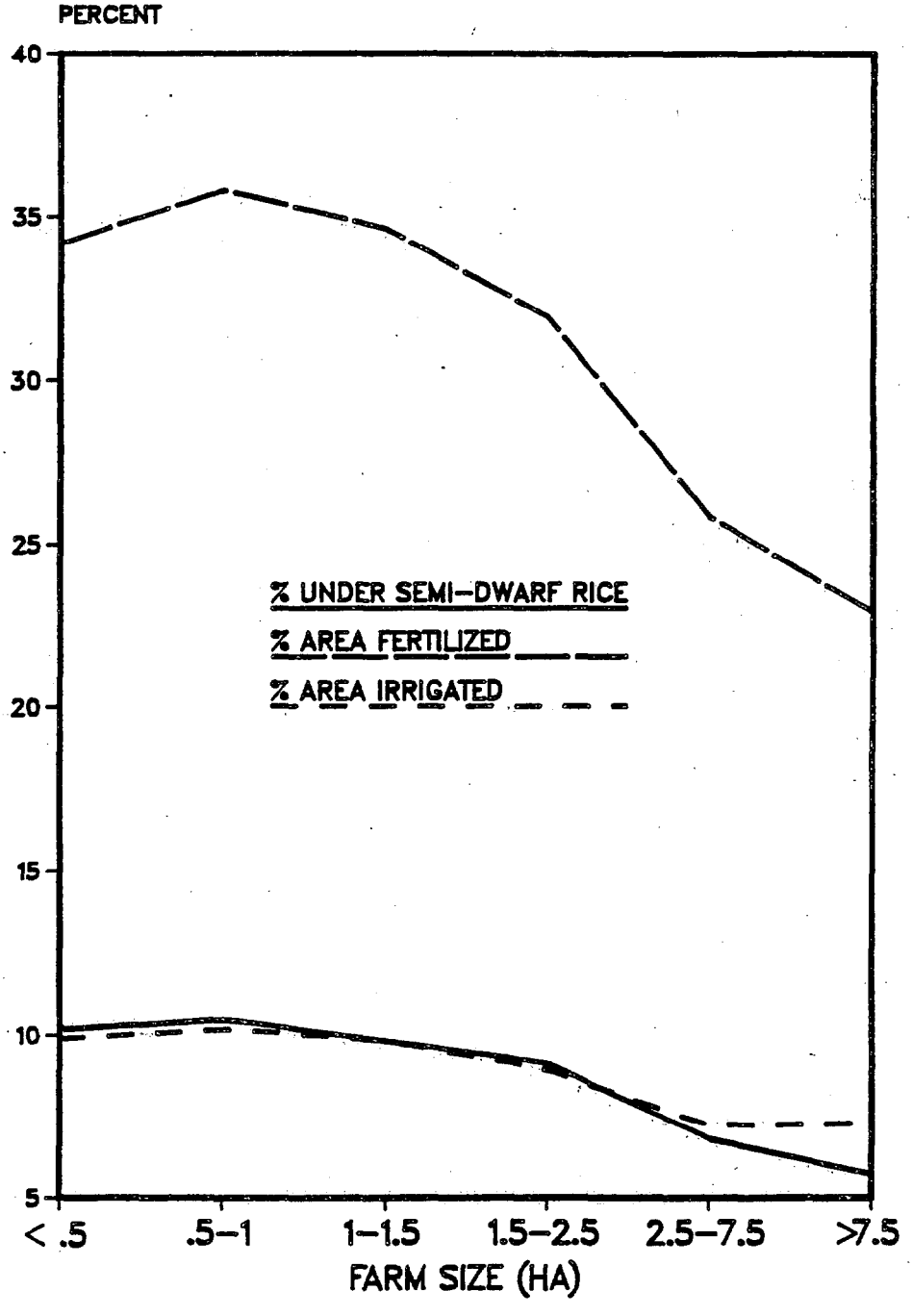
Small farms with more family labor per hectare should do best out of modern varieties. Those with little access to timely inputs probably do badly and thus the centers should continue to investigate how modern varieties might be more robust against their failure.

Producers on small farms could lose land via eviction or foreclosures. There are some notorious cases, e.g., Chilalo, Ethiopia (Cohen 1975, pp.348-9). Mini-holdings in India, however, have increased their share of farms and areas (Vyas 1979). There is no general link of modern-variety adoption or yield to largeness of farm or owner-occupancy. Modern varieties cannot be blamed for machinery subsidies or land reform evasion, although managers of systems who do gain from such abuses have also been quick to exploit the gains from modern varieties (see also section 8.7).

Despite earlier gloomy assessments, most recent work concurs that, if most poor people in modern-variety areas are smallholders and keep their land, modern varieties raise their average net income (Barker and Herdt 1981,

FIGURE 8.4

RELATIONSHIP BETWEEN FARM SIZE AND USE OF MODERN AGRICULTURAL TECHNOLOGIES IN BANGLADESH (BANGLADESH BUREAU OF STATISTICS, 1980)



Pinstrup-Anderson and Hazell 1984) and consumption (see Feature: Rice and North Arcot). But do they make it less stable? India's sorghum, millet, and all-foodgrain yearly output variability has risen in the post-modern-variety period (e.g., Hazell 1982, 1984, Walker 1984, and chapter 6). But output variability, especially variance but also even coefficient of variation, is a bad measure of riskiness. It has been raised nationally, mainly because yields and modern-variety areas vary together, not because individual farm outputs vary more (let alone are worse in bad years than for traditional varieties); the reverse is the case. By seeking greater genetic diversity and otherwise, the centers will continue to reduce individual disaster risk.

Feature: Modern Rice and North Arcot, India

North Arcot, an important rice growing district in S. India, has benefited substantially from improved rice varieties. Prior to the release of modern varieties, average yields were growing at an annual rate of about 1.4 percent. With the release of modern varieties in 1966/67, this growth rate accelerated nearly 4 percent per annum, providing an accumulated yield increase of over 1 t/ha by the early 1980s.

The first modern varieties released in North Arcot were Taichung Native 1 (from Taiwan) and ADT27 (developed locally). Beginning in the early 1970s, these varieties were rapidly replaced by IR8 and IR5. Of the 38 paddy varieties released in the area since 1975, 23 had IRRI germplasm in their parentage. The share of the paddy area planted to modern varieties increased from 20 percent in 1970/71 to 90 percent in 1981/82.

Modern varieties were the predominant source of growth in rice yields, but also important were sizable increases in the use of fertilizers, pesticides and irrigation water. The latter was achieved through increased investments in wells and mechanical pumping equipment.

CH. 8 8/16/85

Total rice production has increased faster than yields because of a concurrent but modest increase in the gross cropped area. This is attributable to a combination of increased irrigation and the shorter growing period requirements of the modern varieties. In a sample of villages, the cropping intensity (ratio of gross to net paddy area) increased from 1.75 to 2.06 between 1973/74 and 1982/83.

These changes in rice production had widespread ramifications on the region's farm and non-farm economy, which can be analyzed using detailed socio-economic surveys conducted in 1973/74 (by Cambridge and Madras Universities) and in 1982/83 and 1983/84 (by IFPRI and the Tamil Nadu Agricultural University). A useful aspect of these data sets is that the samples of households were drawn from the same representative villages.

The average household in the sample villages more than doubled the real value of its consumption of food and consumer goods and services between 1973/77 and 1983/84. Further, this gain seems to have been shared by different types of households in rough proportion to the value of their total consumption in 1973/74 (Table F8.1)

These increases in the value of per capita consumption were accompanied by a shift towards more varied diets, with all household types increasing the share of pulses, livestock and horticultural products consumed relative to cereals. There were also significant increases in the proportion of household

Table F8.1 Comparison of the mean value of total consumption by different household groups in North Arcot, (constant 1973/74 prices)

Household Type	1973/74				1982/83[a]				1983/84	
	All Villages		Poor Villages		All Villages		Poor Villages		Poor Villages[b]	
	Rs.	Index	Rs.	Index	Rs.	Index	Rs.	Index	Rs.	Index
Small Farms[c]	1369 (110)	137	1142 (79)	113	1823 (107)	151	1635 (183)	131	2890 (136)	113
Large Farms[c]	2273 (242)	228	2346 (225)	233	3604 (237)	298	3483 (324)	280	5752 (694)	225
Paddy Farms	1962 (136)	196	1559 (138)	155	2822 (158)	233	2804 (245)	225	4418 (255)	173
Non-Paddy Farms	1458 (352)	146	1184 (369)	117	2215 (409)	183	1949 (593)	157	3329 (561)	130
Non-Agricultural Workers	1413 (101)	142	1162 (206)	115	1727 (294)	143	1114 (241)	89	2190 (215)	86
Agricultural Workers	998 (53)	100	1008 (67)	100	1209 (55)	100	1244 (101)	100	2553 (96)	100

Notes: Figures in parentheses are standard errors of estimates for the means. The index numbers reported are within year indexes of inequality using the total consumption of agricultural workers as the base.

a Drought year.
b Only poor villages were samples in 1983/84.
c Small farms operate 1 ha or less; large farms operate more than 1 ha.

CH8:8/16/85

expenditure allocated to durables, medical care, transport, entertainment, house improvements, and religious and social events. The data did not include information on intra-household allocations so effects on the basis of gender and age, for example, cannot be differentiated.

When compared to the earlier rice varieties, the modern varieties use a little more labor per hectare but less labor per unit of paddy (Table F8.2).

However, the labor requirements for rice production have declined for all varieties since 1973/74 because of the increased mechanization of irrigation pumping and paddy threshing. Mechanization of land preparation is still not widespread in North Arcot.

Total employment in paddy farming increased slightly between 1973/74 and 1983/84. The average farm increased its total labor use in paddy from 88 days to 94 days of male labor and from 70 days to 83 days of female labor. Of these amounts, about one-third of the male labor is hired and two-thirds of the female labor is hired. There has been very little change since 1973/74 in the composition of labor use.

Agricultural wages vary by operation, gender and village, but there has been a general pattern of increase since 1973/74. The average daily wage for plowing (which is performed by men) in the sample villages increased from Rs. 2.23 in 1973/74 (Rs. 4.11 in 1982/83 prices) to Rs. 5.10 in 1982/83 - a real increase of 24 percent. Similarly, the average daily wage for transplanting

Table F8.2--Labor use in paddy production, North Arcot

	100 hrs/ha season	Hours/ 100 kg
Pre-modern varieties		
1972/73	19	89
1982/83	17	57
Modern varieties		
1972/73	20	64
1982/83	18	50

(performed by females) increased from Rs. 1.17 in 1973/74 (Rs. 2.16 in 1982/83 prices) to Rs.2.45 in 1982/83 - a real increase of 13 percent. During the same period, in-kind daily wages for harvesting (performed by female workers) increased by 11 percent and in-kind daily wages for threshing performed by male workers increased by 21 percent.

Initial estimates also show strong growth linkage effects to nonagricultural employment in the local towns. The total number of fulltime workers in the region increased by 30 percent between 1971 and 1981. Of this increase, about one-third of the jobs were created in non-agricultural activities. Ignoring other less important sources of growth, each 1 percent increase in the value of agricultural output was associated with 0.6 percent increase in agricultural employment, and a 0.9 percent increase in non-farm employment.

END Feature

CH. 8 8/16/85

8.4.4 The real poverty problem: where modern varieties are not

Focus on small-scale farmers in modern-variety areas may have distracted attention from areas that have not much used modern varieties. Yet observers concur that such neglected areas have done badly (Ruttan 1977, p.18, Barker and Herdt 1984, p. 48). Poor wheat farmers and their employees in Madhya Pradesh, selling wheat to buy inferior coarse grains, lose absolutely when Punjab's burgeoning wheat output depresses prices. In non modern-variety areas with poor soils, initial poverty tends to be worse, and less unequal (Dasgupta 1977a), so that the chance of fairly shared gains would be better, if modern varieties do eventually take off.

There are exceptions. In Taiwan, all zones grow mainly irrigated rice, so all gained from modern varieties. In Pakistan, rainfed zones gained too from modern-variety wheats and regional inequality fell (Rochin 1973, Chaudhry 1982). But usually the poorest, less irrigated zones (Pacific S.W. Mexico, the E. Indian rice zone, Mindanao) have lost as the modern foodgrain varieties pushed leader zones further ahead (Tuckman 1976, Brass 1984). Non-foodgrain and off-farm growth, and even irrigation, did little to compensate.

Zones are big places, and mask much more localized effects. In India, slow-growing districts in the modern-variety period had in 1962-65 shown no worse initial land quality and yield, but much worse initial labor-productivity and hence poverty, than the faster grower districts (Bhalla et al. 1983, Table 17). Of course, widening productivity gaps have cumulatively disadvantaged poor farmers (and laborers) in the neglected districts. Even at

the village level, within similar (semi-arid) environments, inter-village differences in modern-variety benefits far outweigh intra-village differences. Caste and ethnic group do not appear to explain any of this (Gibbons et al., n.d., pp.194, 205, Herdt and Capule 1983, p.32). An additional productivity gap may also be emerging between men and women in agriculture, where task or land allocation is gender-specific, if male tasks become more capitalized or mechanized than female tasks or if female production of relish and reserve crops is pushed onto marginal or more fragile land.

This highly localized regional disparity, plus the known general problems (e.g., drainage of rainfed, especially upland, rice: inadequate N retention in semi-arid areas), suggest at least one approach to progress. First, find out why some villages in backward zones overcome the problems and do well with modern varieties (e.g., even in Orissa, 30 percent of rice was in modern varieties by 1978-9 (Herdt and Capule 1983, p. 49). Second, ask if institutional factors (fertilizer distribution, credit?), or modern-variety-ecosystem interactions, explain the successes. Third, shift research priorities towards stability in marginal environments (cf. CIMMYT 1983. p.VIII).

Where are shares of foodcrop research-budgets, either of centers or national programs, far below shares of foodcrop consumption, output, land or worktime? In general, center allocations for rainfed crops in Africa already exceed their proportionate contribution to output (chapter 2). But where they occur, do less than proportional allocations correspond to poor prospects of

research results and, if so, are there remedies, e.g. via researching modern varieties of alternative crops for these areas? For African research, the huge shortfall is for root crops (Judd et al. 1983, Lipton 1985). Can this be justified, or does it impede successful work by IITA for these regions? Similar questions throughout the international and national centers -- and much more work on arising from poor farmers' perceived needs, are essential to avoid neglecting either the poorest producer regions or the poorest consumers (section 8.3.3).

Research on irrigated areas may be running into diminishing returns, at least for poor producers, but much of the centers' professionalism remains concentrated there. National research systems (under urban pressures) stress irrigated areas, because they deliver surplus food, especially rice or wheat, to middle-income organized urban workers. Have the centers moved as far as they can to correct for that emphasis? One alternative of migration from rainfed areas has high costs, soon meets limits of absorption, and has nothing like sufficed to prevent deepening relative, and often absolute, poverty there.

8.4.5 Adoption and the research agenda

Research on small-scale farmers in modern-variety sorghum, millet, wheat and rice areas has repeatedly chartered who adopts: whether soon or late; over what proportion of area; with what other inputs; and with what farm yield, profitability and income. Sharply diminishing returns have set in to this type of research, much of it carried out by researchers outside the centers, and social scientists need to rethink their research agenda. Five reasons are advanced as to why such research reveals so little about how modern varieties affect poverty, even in modern-variety areas.

First, given the area, region, and crop-mix, size alone has limited effects on a farm's capacity to generate net farm income from the modern-variety crop; slope, terrain and water systems greatly alter such effects (Colmenares 1975, p.21, Cutie 1975, p.23). Second, while such capacity is related to returns from all farm activity (net of production costs), modern-variety crops' effects on other crops and non-farm outputs are almost unresearched. Third, such returns are only part of poor household net income from all sources and non-farm activity and modern-variety benefits do interact, sometimes favorably (Herdt and Mandac 1981, p.394). Fourth, such income is weakly correlated with net income per person; larger farms mean somewhat larger families, yet (given size of farm) larger families tend to be poorer (Lipton 1983a), and family size is often correlated with modern-variety adoption (Herdt and Capule 1983, p.32, Malla 1983). Fifth, modern varieties affect net disposable income per person not only via net income, but also via obligations -- debts, bribes and family labor requiring feeding (Cohen 1975. p.374) and by switching the distribution of resources between members of households.

Thus research in modern-variety areas should shift from size, adoption and yield issues to efforts to trace how modern varieties affect real disposable income per person in poor farm households. Since poor people gain from modern varieties mainly as food consumers, and lose from them mainly in non-modern-variety areas (section 8.4.4), and since the world's poor increasingly are landless laborers, poverty research related to modern-varieties should probably shift away from "farm households in modern-variety areas" to some of the issues raised in the following sections.

In summary, research that might restore balance would avoid some of the following problems that have beset many socio-economic evaluations of modern varieties effects on the poor:

(a) Asking the wrong questions, e.g., "do small-scale farms adopt modern varieties" instead of "do farmers with poor families gain from modern varieties".

(b) Looking only at first-round effects, e.g., "more modern-variety output cuts food prices to poor employees", but not e.g., "and employers may then reduce wages".

(c) Seeing the action only where it is, e.g., successful modern varieties may divert resources from unaffected, often poorer, regions, at the same time cutting farm-gate prices there.

(d) Isolating modern-variety effects, e.g., more protein from Opaque-2 maize need not bring better diets to undernourished children.

(e) Isolating individuals from groups and relationships, e.g., modern varieties may affect poor individuals by changing relations between lenders and borrowers, or between members of households.

(f) Isolating economic effects of modern varieties from their context, e.g., if populations grow, if landlords' power changes, this affects the poor interactively with major technical change.

8.5 Labor and the Modern Varieties

The distributional consequences of adoption of modern varieties for farmers are complex and somewhat ambiguous, depending on how operators of farms of different sizes act differentially, for example, in actions to seize scarce credit, water and fertilizer from the poor (Kryeger 1974). Absolute gains for laborers from modern varieties are less ambiguous but such gains, initially large, appear to be dwindling (Smith and Gascon 1979, Smith et al. 1985, Jayasuriya and Shand, 1985). Modern varieties raise labor-demand per hectare, especially around harvests (and for double-cropping), pushing up employment. But ample, mobile and growing labor-supply, and increasing mechanization in some areas, keeps real wage-rates from rising much. Modern varieties raise demand for land by less but usually land-supply cannot respond much, so rent and land values rise.

In summary, there are likely to be significant rises in labor use, but not in real wage-rates, big rises in land values and rentals and probable falls in labor's share of but not absolute value of income. Farm families, made less poor by modern varieties, take more leisure leaving a larger part of labor-income to landless hired workers. Unfortunately, the seasonal labor shortages linked to modern varieties, increasingly, induce labor-displacing inputs (threshers, tractors, weedicides) that also come into use in other seasons. The centers should perhaps try to steer research, and modern varieties, towards patterns that discourage such results.

8.5.1 Labor use, wage rate and factor shares

In the wake of modern varieties as rural income rise and job-markets displace self-employment, the proportion of days supplied to the workforce (adult participation) falls, and the proportion of workforce-days demanded, i.e., unemployment rises, (Dasgupta 1977a, esp. p.172). Developing country rural unemployment grows because population and thus workforce rise faster than participation falls (Lipton 1984). Labor demand linked to modern varieties has moderated this unemployment. Early observers of modern varieties found that they raised labor use per hectare-year by about a fifth (ADB 1977, p.60, Barker and Herdt 1984, p.38). As modern varieties spread to less favourable environments, yield impact and employment benefits fell.

But labor/output ratios have usually fallen too. The main reason, (a) mechanization outpacing migration, is discussed in the next subsection. Others include (b) rising costs of finding work and supervising hired labor, (c) institutional change that destroys traditional labor arrangements (Hayami and Hafid 1979), (d) more hopefully, growing off-farm work chances, (e) subsidies for labor-displacing inputs, and (f) most worryingly, research addressed to reducing per-hectare costs of techniques that use machinery and fossil fuels, helping to displace labor on big farms.

Despite recent declines, modern varieties impact on employment usually remains positive. But few significant rises (as opposed to fluctuations) in real wage-rates are found in Asian modern-variety areas (Kumar and Sharma 1983, Jayasuriya and Shand 1985). Extra work is absorbed by extra people, who

compete real wages down to near-subsistence. Without modern varieties, many more of these people would have been jobless or dead, especially as higher food prices would have pushed "subsistence" wages lower still, as happened in many non-modern-variety areas (Jose 1974, Parthasarathy 1974). Modern varieties mean a higher real wage bill -- but usually it absorbs less than 10 percent of extra modern-variety incomes, the rest going to landowners and input suppliers (Crisostomo et al. 1971, Burke 1979, Ahmed and Herdt 1981). The following additional considerations also bear on the issue of employment. Hired labor households, sharing the wage bill increased by modern varieties, are themselves increasing: mostly this is Malthusian, but sometimes extra modern-variety-based resources and power help "the village rich to turn the poor off their land" (van Schendel, 1981, p.245). Little is known about how modern varieties affect off-farm, or non-modern-variety crop, wage-rates or employment or about effects on labor in non-modern-variety areas. Finally, though "laborers" gain absolutely from modern varieties, particular vulnerable groups may lose. The above remarks are oriented to Asia and to some extent Latin America. More work is needed on these issues in Africa, especially where high rates of out migration particularly by males may induce new complications in the modern variety picture.

The impact of modern varieties on the structure of labor use can be considered in two convenient categories, namely, by groups and by timing. Hire labor as a group increases more than family labor (Visaria 1972, Barker and Herdt 1984, p.39). This helps the poor in irrigated areas where poverty is concentrated among the landless (Lipton 1983). Modern varieties also probably shift demand from casual to longer term hired workers, reducing numbers in poverty but increasing its severity for remaining casuals.

Some village data suggest that both trends reduce women's share in cash income. A systematic study in India, however, related total female labor positively to modern-variety rice in all three states surveyed (Agarwal 1984). There are many documented instances, particularly but not exlcusively in Sub-Saharan Africa, where modern technologies have differentially affected the structure of male and female labor use. One study of food farming among the Nigerian Tiv analysed differences in male and female labor roles, income sources and financial responsibilities and showed how adoption of the recommended technologies and package of practices would have raised women's labor input relative to men's but not provided them with a commensurate financial reward; since the potential for women to absorb labor increases of the magnitude required was limited, the net result was a decrease in the anticipated volume of farm household production (Burfisher and Horenstein 1985).

On timing, modern varieties usually help the rural poor by stabilizing labor demand, wages and employment within and across seasons (Dasgupta 1977, p.336, Barlow et al. 1983). Unfortunately, some center research such as that on threshers, transplanters and commercial weedicide potentially undermines this benefit, while work on fertilizer placement may strengthen it. Since post-harvest labor is especially at risk, screening of modern varieties for post-harvest characteristics, notably amenability to labor-intensive processing and protection, is desirable although admittedly difficult. Research on second-season crops has helped to increase total labor use. It could help to

avoid labor displacement if shorter-duration varieties were sought, even at some sacrifice of yields, thereby making threshers and tractors less attractive to speed up the turn-around between crops.

Between years, modern varieties have probably raised national-level variability of crop output, and a fortiori of labor hire, by raising the covariance among high-output areas (Hazell 1984). In almost every Asian village, however, farm employment, even in a bad year, is raised by modern varieties.

8.5.2 Modern varieties and the laboring poor: mechanization vs migration

Tractors, two-wheelers, threshers, even mechanization of irrigation, normally displace considerable labor (Binswanger 1978, Joshi et al. 1981, Farrington and Abeyratne 1982, Jayasuriya et al. 1985). Claims that they avoid this by raising cropping intensity usually collapse when modern varieties, water, etc. are allowed for (Agarwal 1981, 1984). Indeed, tractors may displace more labor in double-crop systems because animals and their care are more completely replaced (Cordova et al., 1981). But do the centers' activities forge, strengthen or break the links between modern varieties and mechanization? Machinery cannot usually be paid for, per hectare, out of very low traditional variety yields, and double cropping reduces tractor and thresher downtime and increases gains from timeliness. But should the centers work to develop, or cut the farm costs of, mechanical reapers — "a very profitable investment" (Moran 1982) because they reduced employment of poor

harvest laborers by 80 percent -- or tractors or threshers? In rare circumstances (such as in E. Zambia) such inputs can permit extra land to be farmed; or reduce drudgery, not employment; or create voluntary leisure for some farmers. But deeper unemployment for the bitterly poor, with little or no output gain, is a more common result.

Migration, unlike mechanization, eases seasonal modern-variety peaks by spreading work (to people from neglected areas), not destroying it. Typical migrants are either better-off villagers headed for towns, or the poor seeking farm work (Connell et al. 1976). Modern varieties affect these groups differently. Technology developers working in and with the centers probably should know more about how alternative modern-variety strategies and farm systems affect migration and hence wage-rates, incentives to mechanize, and jobs. For modern-variety gains to stay with poor workers, and not just machine-owners and labor-saving farmers, new farming systems should spread peaks to attract enough immigrants to restrain the development of seasonal wage peaks and hence labor-displacing mechanization. Some center research may have neglected or discouraged the migrant-employing response to seasonal labor peaks, and encouraged or cheapened labor-displacing alternatives. Doubtless some of the more "successful" engineering work discussed in chapter 17 could be so described, for instance.

While modern varieties cannot simply be absolved from any linkage with labor-displacing inputs at some times and places, they do initially raise the demand for labor, and cheapen food for laborers. Moreover, it is only because

a worker owns neither the land nor the machines, that he or she suffers when "displaced" by them. Population pressure and inadequate rural off-farm activity worsen the suffering.

Therefore, the centers' research should significantly be directed towards varieties and technologies with increased labor/land and labor/capital ratios, in the contexts of land and asset ownership and of population growth facing rural employees. These are in Asia now, and in Africa soon will be, a growing majority of the poorest. Saying that modern varieties and the centers with which they are associated are not to blame for those contexts, while true, does not come to grips with the death, pain and poverty that unemployment causes. An integrated research approach to such problems should presumably be high on the agenda of both national and international concerned organizations.

8.6 Poor People's Consumption and Nutrition: Impact of Modern Varieties

8.6.1 Food production and nutrition

Changes in food production affect nutritional status to the extent that food consumption of malnourished individuals is affected. The nutritional effect of changes in food supply depends on the distribution of effects which, in turn, depend on how the supply change occurs - which commodities, how prices are affected and whether there are simultaneous changes in incomes of malnourished groups.

Although many factors contribute, insufficient energy and protein intakes are usually a result of inadequate household food acquisition power and behavior. "Household food acquisition power" combines the effects of household self-provisioning, purchasing power, food prices, food availability and resource control (Pinstrup-Andersen 1985). Increase in food production resulting from technological change may increase self-provisioning and purchasing power (of producer households), reduce food prices (thereby adding to food acquisition power of nonproducer households) and will increase food availability. Imports, food subsidies or direct distribution each lack one or another of these effects.

In low-income countries, the poorest 20 percent of people spend 60 percent and upwards of their income on food and, even then, are able to purchase much less than the amount judged nutritionally sufficient. Thus, production increases that drive down real food prices help the poor the most. The relative importance of individual commodities in the food budget of the poor varies among countries. In some, one staple may account for 40-60 percent of food energy and expenditures, while in others no single staple is dominant.

Table 8.1 illustrates the differences in the contributions that two staple foods make to the diets of the 10 percent poorest and the 10 percent wealthiest sectors of several countries. In the Sudan, people in the lower of these groups consumed less than half the rate of energy judged to be sufficient, and obtained about 20 percent of this energy from sorghum: the higher groups

Table 8.1 Proportion of food energy from and of expenditures on two principal staple foods in five developing countries

		Lowest 10% per capita income		Highest per capita income[a]	
	Staple	% of energy	% of expenditures	% of energy	% of expenditures[b]
lombia	Rice	17.6	12.4	14.5	6.1
	Cassava	7.9	5.6	4.1	2.0
ypt	Wheat	47.3	12.6	38.7	2.1
	Maize	12.3	2.2	10.4	0.3
i Lanka	Rice	47.2	26.6	33.4	7.8
rban)	Coconut	16.8	7.3	15.0	2.7
dan	Meat	28.0	13.6	34.4	11.0
	Sorghum	19.5	6.7	5.9	2.3
ailand	Rice	89.3	34.5	48.1	1.8
	Wheat[c]	0.1	0.2	2.7	1.1

urce: provided by IFPRI Food Consumption and Nutrition Program.

For Colombia, data here refers to average of all income groups, for all other countries data refers to the highest 10% income group.

Data show % of total food expenditure on each item for Colombia, and % of total household expenditures on each item for other countries.

Consumption of cassava, millets, sorghum and other root crops all below 0.5% of total food energy in Thailand.

of consumers obtained about five percent of their energy from sorghum. All groups got a higher proportion from wheat which is clearly a preferred staple, because its consumption increases as incomes rise. Thus, even though sorghum is a "poor person's crop", changes in wheat prices may have a greater impact on the poor than changes in sorghum prices. These kinds of counter-intuitive effects are also observed in other countries.

Because food accounts for such a high proportion of poor people's expenditure, reductions in food prices have a greater relative benefit to poor people than to the wealthy. The increase in consumption rate results when food prices fall and depends on preferences and other needs of the households concerned, but generally a large fraction of additional income goes to food purchases in low income households. In developing countries for which data are available, the same reduction in prices leads to twice the relative increase in real income for poor households as for the rich (Table 8.2).

Modern varieties have moderated the threat of rising real food prices. In the early 1980s, if they had been replaced by traditional varieties (with other inputs unchanged), yearly developing country rice output would have been 10-27 Mt less, and wheat 7-20 Mt (Pinstrup-Andersen and Hazell 1984). Other crop modern varieties added at least 3-5 Mt. Other inputs, worth applying thanks to modern varieties, probably raised the food output increment by over 50 percent. Yet in India, with an increment of perhaps 12 Mt, yearly food

Table 8.2 Impact of a 10 percent decrease in the price of food on real income of low and high income population groups

Country	Percent increase in real income: Lowest 10% per capita income	Highest 10% per capita income	Source
Sri Lanka	8.5	4.1	Sahn (1985)
Thailand	6.0	2.0	Trairatvarakul (1984)
Egypt	5.6	1.0	Alderman and von Braum (1984)
India	7.3	2.9	Murty (1983)
Funtua, Nigeria	7.7	6.5	Pinstrup-Andersen and Uy (1985)
Gusau, Nigeria	9.0	5.7	Pinstrup-Andersen and Uy (1985)
India[a]	5.5[b]	1.2[c]	Mellor (1978)

Source: IFPRI Consumption and Nutrition Program

a Foodgrains only.
b For the lowest 20 percent.
c For the highest 5 percent.

availability per person has barely outpaced population. Apart from feeding the larger population, extra modern-variety output was used largely to replace imports and build stocks. Some countries' trade policies "fixed" food imports: in Colombia, therefore, rice modern varieties raised availability, cut prices and, in 1970, raised incomes in households with income below $600 by 12.8 percent — over half at the expense of producers, especially in non-modern-variety areas (Scobie and Posada 1978, and see Feature on Colombia). Poorer producers' price losses are reduced because they (a) switch into other crops, if modern-variety crop prices fall much faster than unit costs of production, and (b) "internalize" some consumer gains by eating large parts of extra modern-variety output themselves (Hayami and Herdt 1977). Poor consumers, including such semi-subsistence producers, usually gain most if modern varieties affect goods that are little appreciated by consumers with higher incomes such as cassava in Brazil or Colombia (Pinstrup-Andersen 1977, Pachico 1981).

But the poor's consumption gains have limits. (a) If income (including initial modern-variety) growth favors the rich, modern-variety output will tend to displace imports, not cut domestic prices, (b) If modern varieties restrain staple-food prices, employers can restrain money-wage rises, especially with plenty of underemployed and mobile workers, leaving real purchasing-power little improved, (c) In non-modern-variety areas, poor farmers (often selling wheat or rice to buy inferior foods) and their employees lose consuming-power as the price of modern-variety crops fall, although in middle-income developing countries they are outnumbered by poor urban gainers (Scobie and Posada 1978), and (d) By directing some effort on protein and "food quality", it is conceivable that the centers may have delayed modern varieties' potential to provide cheap food energy to poor consumers, just as thresher/reaper/weedicide research has partly eroded modern varieties potential to provide labor income to poor employees.

Modern varieties have, by moderating food prices, been the main factor improving the nutrition of the poor of the developing world. Such improvement is clearly close to the centers' central objective. How they can help depends on who is vulnerable to what sorts of undernutrition, where, when, by how much, and with what trends. Correct perception of undernutrition implies regional, commodity, and varietal priorities. Some modern-variety research resources have been diverted to topics unrelated to the main causes and incidence of undernutrition. Poor at-risk consumers need preferably cheaper, more food energy, stabler and more easily absorbable — rather than, say, high-lysine maize.

Major modern-variety-based rice and wheat improvements have prevented mass starvation in much of Asia. Wheat progress has displaced pulses, but wheat gives much cheaper dietary energy -- and 90-95 percent of undernourished people lack energy more than protein. But in Africa, and in semi-arid Asia, modern varieties of wheat and rice have done much less for poor consumers; they eat mainly sorghum, millet, maize and cassava. Hybrid maize, which has partly displaced sorghum, a less vulnerable crop, has progressed very slowly since 1970. Sorghum progress is confined to major, recent advances in limited places and seasons, mostly in India.

Inferential evidence suggests that rice and wheat modern varieties have substantially improved urban, irrigated small-farm rural, and (in lead areas such as the Punjab) irrigated landless rural nutrition in Asia and Latin America; but that rural Asians in unirrigated areas (with some Indian exceptions thanks to kharif sorghum, pearl millet and finger millet) suffer at least as severe energy deficiencies as 10-15 years ago, whereas the poorer rural African eats considerably less, and with greater fluctuations. As and when adopted, IITA'S mosaic-resistant cassava modern varieties will help the latter energy problem -- as they have in Indonesia -- but cassava, exceptionally, does create protein problems as a main staple. Since legumes produce more costly protein (and much more costly energy) per hectare than cereals, legume research has fewer nutritional benefits than is often supposed, but can reduce dietary monotony and vulnerability to drought. The centers working on food legumes might usefully identify further how they can best help nutritionally vulnerable target groups.

The main nutritional deficiency is energy. The main vulnerable group comprises the ultra-poor (10-15 percent in low-income countries), especially under-fives. They ingest mainly coarse grains, roots, cheap wheat or rice modern varieties, or breastmilk/gruels based on these. Risks from undernutrition are synergistic with illness, and greatest in lean seasons and years. Under-fives are heavily over-represented among the ultra-poor (Schofield 1979, Chambers et al. 1981, Lipton 1983a), who comprise most rural landless, unskilled urban jobless and households headed by women, plus many households of African small-scale farmers and Asian micro-scale farmers without access to irrigation.

FEATURE: Modern Rice Varieties and Human Nutrition: The Case of Colombia

The centers seek to develop new agricultural technology to improve human welfare. It is therefore pertinent to enquire whether there is evidence that human welfare has been enhanced following the successful introduction of new technology. The case of rice in Colombia affords such an opportunity.

In the mid-1960s, almost all of Colombia's irrigated rice production was based on tall varieties with yields of less than 3 t/ha. Today irrigated rice production is based solely on modern varieties and the yields are over 5 t/ha. Colombia today produces over 1 Mt more rice than it would have done with traditional varieties on the irrigated areas. Earlier studies have shown that the annual rate of return to investment in rice research was between 80 and 90 percent.

Of particular interest is the impact of this increase in rice production on human nutrition. It is widely recognized that nutritional status reflects education, access to health services, distribution of potable water, and occupation, as well as food intakes. To attribute changes in some measure of nutritional status solely to changes in food consumption would be quite erroneous. For this reason, the change in energy intake is used as a measure of the impact of the modern varieties.

The Department of National Planning and the National Statistical Office in 1981 conducted a survey of 9000 households representing over 90 percent of the Colombian population. The survey gathered information about (a) household size and age-sex composition, (b) location (rural/urban), (c) food expenditure, and (d) food consumed, including subsistence production. A 24-hour recall food consumption survey was also conducted for 3000 households. Based on the overall results of the survey, the summaries of Table F8.3 were constructed.

Rice represents 6 percent of total food expenditures on average but, among the lowest income group, it represents 17 percent of total energy consumption.

From the 9000 households, those with incomplete data on income were excluded leaving 6093. Of these, those comprising the lowest 30 percent of incomes were selected, making a total of 1828 households. Extreme values of prices and/or energy intakes were excluded leaving 678 urban and 1024 rural households. The analysis was restricted to 10 major food items. The shares of energy are reported in Table F8.4.

The first part of the study (conducted by Muchnik 1985) focused on the impact on total energy consumption of rice consumers. The consumption of each food was expressed as a function of the prices of each of the 10 foods, family income, family size and the proportion of children under five years. From these estimates it was possible to derive a relationship between changes in energy intake and the price of rice.

Table F8.3 Summary nutritional data

(a) National expenditures and consumptions of major foods

Food	Share of total food expenditure	National annual average consumption
	percent	kg/adult equivalent
Dairy products	10.1	71
Plantains	5.0	69
Fruits	6.7	62
Potatoes	5.0	56
Sugar	8.7	54
Vegetables	7.1	41
Rice	6.1	40
Beef	16.7	32
Cassava	2.0	25

(b) Protein and energy consumption averages by income group

Income inter-quintile group	I	II	III	IV	V
Energy (cal/day)	1910	2580	2960	3200	3120
Protein (g/day)	40	60	74	83	85

(c) Share of selected foods in energy consumption by income (percent)

Food	Income					
	I	II	III	IV	V	National average
Sugar	20	20	19	18	18	19
Rice	17	15	14	14	13	14
Fats	9	10	12	13	14	12
Root Crops	15	13	11	9	7	11
Maize	9	8	6	5	5	6
Dairy Products	4	6	6	6	7	6
Meat	3	5	6	6	7	5

Table F8.4 Share of total energy intake of selected foods among the households comprising the lowest 30 percent of incomes

(percent)

Food	Urban	Rural
Sugar	22	20
Rice	20	16
Potatoes	7	6
Cassava	6	8
Beef	6	4
Plantain	9	10
Maize	8	9
Bread	5	2
Beans	3	2
Milk	4	4

The introduction of modern varieties expanded output and, as foreign trade was insignificant, it augmented domestic supplies. The rate of growth in rice supply was faster than the growth in demand from rising incomes and population so that the real price of rice to consumers fell. Alternatively viewed, the price of rice would have been very much higher had it not been for the expansion of supply engendered by the introduction of modern varieties.

This result depends crucially on the assumption that the government would, in fact, have allowed the rice price to climb to these levels. Given the importance of rice in the diet of all Colombians, it is improbable that such a strategy would have been followed. This illustrates the dilemma which faces an analyst of the impact of a particular policy - namely, what would have happened in its absence. In the absence of modern varieties and with the concomitant tendency for prices to rise, it seems reasonable to expect that some intervention would have occurred. This might have taken various forms including subsidies on the price of rice to low income consumers or increased supplies through imports. The actual policy corresponded to a closed-economy situation with no trade in rice. The prices that would have prevailed under an open economy with rice imports were estimated on the basis of the average c.i.f. price paid by Latin American importers adjusted for tariffs, transport costs and marketing margins.

The average annual decline in rice prices from 1969 to 1981 due to the modern varieties was 55 percent and 14 percent under the closed and open economy policies, respectively.

The increased energy intakes were estimated based on a high and low measure of the response to a fall in rice prices. Under the low response, total increase in energy intake would have been less than 1 percent per capita a year in an open economy. Using the higher estimates of response and a closed economy, the energy intakes rose by 8.7 percent in the urban and 15.3 percent in the rural areas, i.e. on average over the period 1969 to 1981, per capita energy intakes were higher by 8.7 or 15.3 percent per annum. These represent the upper bounds of the feasible estimates. The results allow for any declines in the consumption of nine other major foods arising when consumers substitute more rice for other foods in response to the cheaper rice, i.e., the calculations reflect a "net" increase in total energy intakes.

There are two important features of these results. In the first place, when a commodity represents a significant share of energy intake, the introduction of new technology which increases supplies and lowers price can lead to an important increase in per capita energy consumption. Given that the average per capita intakes of this group in Colombia were below the FAO standards (2,420 k cal/capita/day) and, within the group 42 percent of families did not meet the Colombian standard of 1,970 k cal/capita/day, it is clear that increases of the magnitudes estimated here are potentially significant. Second, however, it must be stressed that the outcome is sensitive to the counter-factual hypothesis: what would have occurred in the absence of the new technology? In the Colombian case, it is useful to demonstrate the effect of trade policy on the outcome. If a good enters world markets, its price is

determined outside the domestic economy. In a small open economy, domestic consumers will not necessarily directly benefit from technological change which increases food production.

The introduction of new technology also affects the income of producers (both adopters and non-adopters) and the demand for labour. As a result of the introduction of modern varieties, the irrigated sector assumed much greater importance in Colombian rice production. Irrigated production needs only about two-thirds of the number of labour units per hectare as does the traditional manual upland rice system. This constitutes a decline in the demand for labor that would represent a loss of income to laborers made up of lower real wages and fewer jobs. By 1981, the income of landless workers was estimated to have been 1.03 percent lower than that which would have prevailed in the absence of new rice varieties. This loss of income is estimated to result in a drop in energy consumption of one tenth of one percent (0.1%) if evenly spread across all landless workers. This is the upper bound on the effect of landless laborers as it assumes that the rice sector is sufficiently large to affect rural wages (a fact which is highly improbable) and it ignores the benefits accruing to this group as rice consumers through lower real market prices. The latter effect, if these workers are representative of rural low income people, amounts to between 1.2% and 3.8% in an open economy, so that the net effect on landless workers was an increase of between 1.1% and 3.7% in food energy consumed.

Finally, there is a group of small farms in the upland sector which faced lower prices and no technological advances. As a consequence, their numbers fell by about 5000. Based on the fall in prices, their incomes are estimated to have fallen on average by 87 percent between 1969 and 1982 under a closed economy, or 41 percent under an open economy. When these estimates were combined with the response of energy intakes to total income changes, it was found that energy intakes among this group would have declined between two and five percent in an open economy and four and ten percent in a closed economy. The lower real prices would offset these declines by between one and four percent in an open economy and by between five and fifteen percent in a closed economy. Again, these must be taken as upper bounds as the estimates are based on the assumption that these farmers had no alternative crops to grow in the face of falling rice prices. It is assumed (conservatively) that they simply maintained their existing level of rice production and suffered the loss in income stemming from lower farm-gate prices.

These results again emphasize the importance of policies in determining the magnitude and distribution of benefits from new technology. A country that protects its non-farm sector and maintains an overvalued exchange rate will discourage output and productivity growth in agriculture. Furthermore, when new technologies are introduced into such a setting, consumers will benefit at the expense of producers, and non-adopters will be particularly disadvantaged. In contrast, in a more open economy the price effect of new technology will be less, and producers will be the primary beneficiaries. Their real income gains

will result in an initial rise in total energy intakes. As their spending on other goods rises, so will real income in other sectors leading to indirect increases in energy intakes among the non-farm sector. While improving human nutrition through increased food intakes amongst the low income groups is unquestionably a desirable goal for the centers, it must be stressed that the final outcomes do not depend solely on the introduction of new agricultural technology. The linkages are complex; different groups will benefit to different extents and, above all, the economic policies of the country can have an overriding effect on the magnitude and distribution of any nutritional improvement.

END FEATURE

8.6.2 Variability, vulnerability and quality

Modern varieties have raised year-to-year national-level variability of cereal output slightly, though on-farm disaster risk has probably generally lessened. But, since farmers meet family needs first, sales for off-farm consumption fluctuate much more than production, as do prices, unless imports are used to moderate such fluctuations. Vulnerable groups' consumption outside modern-variety areas can become very vulnerable. Stocks become more important and, thanks to extra modern-variety output, more feasible, justifying some research on storage characteristics.

Modern varieties have reduced seasonal consumption variability, because output gains (except for kharif sorghum in India) are heavily concentrated in the water-controlled, non-rainy season. But the costs to poor consumers of year-to-year price instability suggest priority for raising yields of more robust crops, especially drought-resistant millets and sorghums to compete with modern maize varieties in African farming systems.

Preschool children, and pregnant and lactating women from poor homes require particular research attention because of their relative vulnerability. More output has helped them by reducing intra-family competition for food, and greater seasonal stability has helped too. But research has ignored the possibly special role, for these vulnerable groups, of modern-variety nutrients and work-inputs. Potentially relevant albeit very challenging issues, especially for national programs in countries where vulnerability is high, include: which processes could cut cost, time, or risk of contamination in

preparing food, especially weaning food? Which crop-mixes and modern varieties, in the context of total diets and activity of vulnerable groups, might help to improve quantity, quality and absorbability of breast milk, and for energy density, nutrient mix, and absorbability of cheap weaning foods? How does timing of seasonal food (and mother's work) interact with these issues? Crops, and perhaps varieties, differ in these respects, as well as in fiber content and anti-nutritive factors affecting them indirectly.

The menu of conventional modern-variety nutrition research has sometimes been of questionable appropriateness through some work on nutrient quality and palatability. Improving maize amino-acid mix via Opaque-2 genes has taken considerable research resources. Protein balance and enrichment works wonders for storage pests, but vulnerable humans do not live by modern-variety cereals alone. Opaque-2 maize modern varieties now yield no worse than others but, to obtain the extra lysine, have the poor unknowingly sacrificed as research resources were switched from energy yield and stability? Probably little, in the judgment of Lipton and Longhurst (1985). ICRISAT, fortunately, established that amino-acids did not constrain dietary adequacy among vulnerable groups, thus avoiding major wastes (Ryan 1984). Only where root-crops or bananas are major staples — and where legumes are unimportant — is it likely that protein research can contribute significantly to poor people's nutrition.

Breeding for palatability, color, and appearance (Ryan 1984) threatens the price discount which makes modern varieties so important for poor consumers. It can make sense if many poor producers, or employees, depend on selling these

crops to the rich. But in general it is yield and stability of cheap food energy that the poor need most. If researchers collaborating with the centers seek more sophisticated quality or nutritional goals, it is on the needs of the most vulnerable groups that they should concentrate in order to seek maximal social relevance.

8.7 Further Insights to the Modern Variety-Poverty Mystery

Despite reservations, both the physical features and the observed effects of modern varieties on smallholders, laborers and consumers seem generally pro-poor. How, then, is it possible that in most of Africa there are few modern varieties and deepening poverty (Ghai and Radwan 1983), and that in Asia a massive spread of modern varieties has been compatible with rising real income-per-person but with little dent on the incidence or severity of poverty (ADB 1977, p.63, Lipton 1983a)?

The approach in this chapter so far has involved taking separate aspects of modern-variety impact such as on employment, small farms and nutrition, and treating them as simply additive. This leaves some unanswered questions: for example, the consumption studies suggest that, while consumers benefit from modern-variety-induced price reductions, producers lose 50-60 percent of what consumers gain (Scobie and Posada 1977, Evenson and Flores 1978), yet the production studies claim producer gains too. More holistic ways to look at modern varieties in their socio-political context are available and may suggest useful new departures. Such ways are offered by economics, political

economy and comparative history and some of these, particularly from the latter are now considered.

Several different types of models have been developed by economists for attempting to examine the consequences of changes beyond the sectors in which their first effects (such as crop productivity gain) occur. Some are neo-classical in that they are predicated on assumptions that all inputs are fully employed and, except for land, freely mobile among activities (Binswanger and Ryan 1977, Binswanger 1980, Quizon and Binswanger 1983). Such models still give unclear predictions of impact on distribution between labor and capital and depend on the exposure of an economy to foreign trade. Whether they show that labor-using and land-saving technical changes like modern varieties benefit labor, depends on the employment effects of any extra equipment involved. Research priorities oriented to assisting the poor could be clarifed, by further development of computable models of this class.

Other more general equilibrium models can trace how extra spending by people initially enriched by modern varieties goes through successive rounds to create extra incomes for others, rich or poor. In a regional model of this kind modern-variety producers in Malaysia generated further 80c of income for every dollar of their extra modern- variety initial income (Bell, Hazell and Slade 1982). Some such effort to trace successive spending rounds, however, seems necessary to a holistic view of the impacts of modern varieties.

Market signals and factor movements, rounds of spending and rounds of production, all significantly affect modern varieties' impacts on the poor and all are neglected in the more simplistic additive approaches of earlier sections of this chapter. While still demanding of data and skill to investigate, all could help the centers and their partners if applied to their problems. In this context it should be noted that the studies reviewed in this section were initiated by or conducted by social scientists working at or linked to the centers, which underscores center concerns for these issues.

In many developing countries the government is a major trader in food staples. Modern varieties thus change its budgetary position. This affects demand, trade, and hence prices, spending patterns and output. Also, modern-variety-induced price changes induce changes in wage-rates. This affects parastatals and, again, government budgets. Both sequences can greatly alter the poverty impact of alternative modern-variety strategies. Examination of such sequences could well further illuminate anti-poverty work at the centers.

Apart from a few distinguished village studies (Hart, n.d., Frankel 1972, Hayami 1978, van Schendel 1981) and some center farming systems work (Collinson 1982, Ghodake and Ksirsagar 1983, Hartmans 1985) there is little work on how modern varieties affect income (let alone status or power) flows and balances within local communities. Farming systems research (chapter 16) is one way forward. But off-farm production, consumption and leisure activities, and transaction relations with particular members of the community, also may substantially affect modern varieties' poverty impact. Some examples exist (Hayami and Kikuchi, 1981) but the issues deserve more attention of analysts in the centers and the national research institutions.

The approaches reviewed to this point do not inform how modern varieties interact with national wealth and power structures. Marxist analysts (e.g., Cleaver 1972, Byres 1972, 1981, Rudra 1978) ask if modern varieties advance rural societies from pre-capitalist formations, formalizing wage-contracts, and polarizing rural communities into capitalists and landlords. The approach, like its predecessors, may err by assuming that large farms have special advantages in using modern varieties. Also, modern varieties were preceded in the Punjab by polarization (and tractorization), and in Java by formalized labor contracts (Chadha 1983, Hart n.d.). The long debate in India about mode of production has involved neo-classicists and Marxists in looking constructively at how modern varieties and power-structures interact within socio-political systems to affect poverty. However, careful scholars stress that there is no general, context-neutral link of modern varieties to class action or to unrest (Byres 1977, Harriss 1977).

Historical methods might possibly help society and its institutions such as the centers to go beyond seeking modern varieties and related technologies that would help the poor and to develop improved technologies and farming systems "poor-friendly" in the real world. Historians have looked at how big agro-technical change systems or "agricultural revolutions" affect the poor. According to their view of the work of historians, Lipton and Longhurst (1985) identify four agricultural revolutions: the Neolithic, spreading southwest and north in Europe from 3500-700 B.C., when hunter-gatherers became farmers: the medieval European (600-1200 A.D.); the 18th century (actually 1650-1850 for N.W. Europe): and today's modern-variety-based green revolution. Four

criteria for identifying such revolutions are: (a) sharply accelerated growth of farm output, or productivity of a scarce input; (b) similarly for all inputs, i.e. discontinuous technical change; (c) linkage of such change to social or political transformation, and (d) major change in mass poverty.

An agricultural revolution is thought worthy of its name when it affects many people and big areas. The medieval revolution took hundreds of years to cover a nation, but was a sudden transformation for each adopting community. Because farmers and villages learn from near neighbors, such major changes concentrate regionally, pulling leaders ever further ahead. Norfolk led England's medieval and 18th century agricultural revolutions (Campbell 1983, Parain 1966, p.179), Riches 1937, pp. 8-17) rather as N. W. Mexico, central Java (Franke 1972), and the Punjab (Lowdermilk 1972, Randha 1974) have pulled away in the modern-variety era on the basis of prolonged earlier innovation leadership.

Much of history suggests that lead regions in an agricultural revolution learn, accumulate, and thus leave the others ever further behind, contrary to the hopes sometimes fed by the assumptions underlying many models used by economists (Myrdal 1958). If so, stronger corrective policies will be needed to help the laggard regions. The international centers, with their relative independence from rich-region pressures, are a special feature of the present revolution. They should, perhaps, gear research more towards backward regions which, on the historical evidence, otherwise will tend to fall further behind.

Can anything be done to counteract such tendencies? In normal times, with normal science (Kuhn 1962) producing a steady stream of innovations, these are probably induced by demand (Hayami and Ruttan 1971). This will come mainly from richer people (and regions), for better-tasting foods and often, where hired labor is troublesome even if not scarce, for labor-displacing methods (Grabowski 1981). In an agricultural revolution, new farming paradigms come from clusters of discovery: the supply side of science. Thus the 18th century revolution in England, far from releasing labor for industrialization, was based on discoveries that were land-saving (laborer/farmer ratios hardly changed) and that created new chances for profit, instead of responding passively to existing scarcities or landowners' preferences (Deane and Cole 1967, p.52, Mingay 1968, pp.25-26, Overton 1979. p.375, Turner 1984, p.225). Similarly the modern-variety aftermath of Mendel (and Crick and Watson?), and the significant historical novelty of the international centers, permits more than passive responses to wealthy farmers' or rich consumers' demand.

Growth of total factor productivity was measured to have accelerated sharply in Japan (1880-90), the U.S.A. (1885-1900, 1938-60), and, following modern varieties, the Punjab (1965-70) (Hayami and Ruttan 1971, p.116. Mohan 1974, p.A-98). Such growth measures come from analyses that may be flawed by omitted factors (Schultz 1964), scale economies, a "coefficient of ignorance" (Balogh and Streeten 19??), as well as discontinuous technical progress. Has such growth a less mechanistic, yet objective, indicator?

Agricultural revolution innovations are, in principle, not seriable (Shackle 1952) (the farm system changes, ruling out piecemeal experiments), not separable (the package is all-or-nothing), and not single-unit (adopters must act together). In practice, only the Neolithic and medieval revolutions meet these criteria (White 1962, Bloch 1966, pp. 242,276, Parain 1966, p.144, Pigott 1981, p.31). Eighteenth century innovations, while bringing more dramatic growth acceleration, were largely gradual, piecemeal, and individual (Riches 1937, pp.5-16, 77-81, Mingay 1968, p.11, Jones 1974, p.88). So are the modern varieties. They rest on repeated waves of pre-modern-variety seed innovations (FAO 1971, P.6, Hayami and Ruttan 1971, pp.158-9, Carr and Myers 1973, p.32, Saxena and Jadawa 1973, p.65). They are set in eminently separable psuedo-packages (Lipton 1979), from which farmers can select by seriable, tiny experiments. Except for timed water supplies, they are single-unit, not resting on neighbors' decisions.

Neolithic, medieval, 18th century, modern varieties: each revolution has involved faster growth than its predecessor, yet smoother technical change. Thus revolutions are increasingly feasible for seriable, separable, single-unit (see previous paragraph) adoption by the poor, but decreasingly associated with rural political transformation, and thus likelier to provide benefits for existing power-structures (even if the agricultural revolution is apparently pro-poor). The expectation is for poverty to decline, but inequality to increase.

At the local level, the modern varieties are like the 18th century revolution in that the new technology did not seem to need or to further, and in practice was not linked to, major change in ownership or organization of farm labor, capital, or power. New modern-variety-linked resources in E. Asia have drastically changed the possibilities of industrialization, rather as the 18th century revolution did in N.W. Europe. Surpluses to invest, food for workers, laggard regions unable to adopt the new methods, and forces to mechanize later: all describe both what the 18th century revolution in England (a little later in France and Prussia) did for national industrial structure and, with allowances for population explosions, what modern varieties may now be doing in Asia.

To conclude these interpretations of history, without modern varieties the poor of developing countries would have been worse off. However, to survive in the face of population increase, land inequality, and industrial country research to cheapen tractors and weedicides and dairy foods, the poor need innovations that help them to accumulate power, assets, or labor income: not only (as modern varieties have achieved) to lose them less quickly. What they need differs according to continent and to their characteristics (landless, semi-arid resource-poor farmers, urban jobless) but modern innovations probably need to be more sharply focused towards these poor people.

The international centers are a new fact of life, not found in earlier agricultural revolutions. Their greatest comparative advantage is relative immunity from the balance of short-run national political forces for research

to respond to the factor scarcities and crop priorities not of the poor but of the powerful. There are important lessons of this history for the centers. Given the particular political system, and each place's poorer target groups, modern varieties and other inputs, methods and outputs can be designed so that the poor can own, use, or control them. For example, male laborers, among the poorest in Bangladesh, gain from systems requiring hand-pumps (Howes 1982). Mini-farmers, still most of the very poor in Karnataka, are likeliest to gain from modern varieties of finger-millets (Rajpurohit 1983). In Colombia, where most of the poor are in towns, cheaper modern-variety rice helps, but more productive maize may help them most (Pinstrup-Andersen 1977). Each set of research priorities has to be reviewed by asking, not only the questions of sections 8.4 to 8.6, but also the question suggested by historical agricultural revolutions: in each major type of concrete situation, who will control the innovations, the systems that allocate them (not only markets), and the spread of gains from them to the poor?

8.8 Coda

* Research has sought modern varieties helpful to the poor by using more labor and supplying cheap food energy. These effects on the poor are real and good. But most of Africa is without modern varieties and is poorer than in 1970, and the incidence and severity of poverty in S. Asia are little changed despite modern varieties. Diagnosis of means to alleviate poverty in these situations increasingly needs to start from the total context of typical poor households.

* As newer modern varieties are bred to resist pests and disease, their advantage over traditional varieties at zero fertilizer has increased even under moisture stress. Still, at zero fertilization, this risks "soil mining". Moderate yield advantages of most modern varieties at zero or low fertilization can be outweighed by price discounts below traditional varieties, and lower straw yield.

* Modern varieties with low photo-period sensitivity thrive despite variable day-length. This permits multiple cropping and smoother flows of food through the year. The poor gain most, since they could seldom save or borrow against lean seasons. But local specificity, not wide adaptability, is now needed.

* Modern varieties increasingly resist moisture stress better than traditional varieties. Millets and sorghum are bred for rigorous root systems. Wheat producers in Pakistan and Tunisia, and rice producers in the Philippines and Bangladesh, have often adopted modern varieties mainly for drought resistance. Most of the poorest people of the world live in vast areas of unreliable rainfed rice, or of semi-arid crops, and most of these areas remain in traditional varieties. Extra targeted research is surely needed.

* Some early modern varieties were indeed "insect pest museums" but most later ones now have better resistance than traditional varieties. Currently, yield increases are bought mainly by raising robustness, not by sacrificing it to yield potential. However, weed research seems to receive few resources. Rats, bird and other vertebrate pests are rather neglected by the centers.

* The narrow genetic base of modern varieties is a danger that is being tackled by the centers. The centers have unprecedented, freely accessible germplasm collections, and have used some wild races in breeding.

* Early studies clearly showed large-scale farmers adopting modern varieties much more readily: later work has shown that small-scale farmers were catching up, often leaving the bigger ones, however, with 'innovators' rents. As for tenure, owner-farmers do not adopt more than tenants, unless, as often happens, tenants get less credit per crop unit area. Small-scale farmers may adopt later because they avoid risk until they have seen their wealthier neighbors succeeding with modern varieties or because they cannot get scarce inputs at first.

* Small-scale farmers ultimately adopt as much and as intensively as others. Having more family labor per hectare, they may get higher yields. There is no general link of modern-variety adoption or yield to largeness or owner-occupancy.

* Areas that have not much used modern varieties have done badly. Poor non-adopting farmers and their employees lose absolutely when burgeoning output depresses prices. Yet, in non-modern-variety areas with poor soils, initial poverty is worse, and less unequal so that the chances of fairly shared gains would be better, if modern varieties do eventually take off.

* Modern varieties raise labor-demand per hectare, especially around harvest, pushing up employment. But ample, mobile and growing labor-supply keeps real wage-rates from rising much. Modern varieties raise demand for land by less, but usually land-supply cannot respond much, so rents and land values rise.

* Few significant rises in real wage-rates are found in modern-variety areas. Extra work is absorbed by extra people, who compete real wages down to near-subsistence. Without modern varieties, however, many more of these people would have been jobless, or dead.

* Developing, or cutting the farm costs of mechanical reapers, tractors or threshers reduces employment of poor harvest laborers. For modern-variety gains to stay with poor workers, and not just machine-owners and labor-saving farmers, new farming systems should spread labor peaks to attract enough immigrants to restrain seasonal high points and hence labor-displacing mechanization.

* In low-income countries, the poorest 20 percent of people spend more than 60 percent of income on food. Its demand and hence price is pushed up by growth of population and of income per head. Modern varieties have moderated this price threat. Poor consumers, including semi-subsistence producers, gain most if modern varieties affect crops such as cassava that are consumed most by poor people.

* Improving amino-acid mix in cereals has taken some scarce research resources. But vulnerable humans do not live by cereals alone. Only where root-crops or bananas are major staples, and where legumes are unimportant, can protein research contribute significantly to poor people's nutrition.

* Without modern varieties the poor of the developing world would have been worse off. However, to survive in the face of population increase, land inequality, and industrial country research to cheapen, say, tractors, weedicides and dairy exports, the poor need innovations that help them to accumulate power, assets, or labor income: not only to lose them less quickly.

* Preschool children, and pregnant and lactating women from poor households require particular research attention because of their relative vulnerability.

* Modern varieties have, by moderating food prices, been the main factor improving the nutrition of the poor of the developing world.

9 HUMAN RESOURCES

9 HUMAN RESOURCES

9.1 Introduction

The CGIAR system recognizes the primary need for developing countries to improve their own capacities to conduct research and is engaged in many different efforts to improve that capacity. These activities can be subsumed under the general term of human capital enhancement. More narrowly specified they include training, education, conferences, workshops, provision of publications and other activities that transfer knowledge or contribute to improving the knowledge base.

The Technical Advisory Committee (TAC) of the CGIAR commissioned a study of training in the system just prior to the impact study being organized so it was agreed that the TAC study would form the quantitative basis of information about training in this report. Much of this chapter is drawn from information assembled and papers produced by the TAC study team (e.g. Bunting, Arajio and Herz 1985).

9.2 Magnitude and Costs

9.2.1 Aggregate indicators

Since IRRI began to provide training in 1962, more than seventeen thousand people have participated in training programs run by the centers, and approximately 3000 a year receive training currently. Many of these people are now national and international leaders who have made professional contributions to research and development of agriculture in the developing countries. Yet there were approximatley 60,000 agricultural researchers in

the developing world in 1980 (Judd, Boyce and Evenson 1984) so the centers' contribution, large as it seems, represents no more than a fraction of all professionally trained people in the developing countries.

The former participants in training provide some of the most important channels of communication between the centers and the national programs with which they cooperate, and they do much to support and promote the work of the centers. Because this is one of the principal ways centers can interact with national programs, all of the centers accept that they are both research and training institutions.

The directly accounted costs of training and conferences consume about eight percent of the core budgets of the centers. However, the total real costs, which are not precisely known, are somewhat more because the training uses staff time and the physical resources of the research programs and services of the centers, which are met from other categories. The nominal cost in 1984 was about $13.5m. Though financial stringency has tended to restrict spending of core funds on training, the volume of training has been maintained, in several centers by special projects.

9.2.2 Types of training

The chief types and means of training provided or promoted by the centers include:

(a) General and specialized courses for groups, lasting from one week to several months, often through a crop cycle, intended to acquaint participants with the methods and results of research at the centers;

(b) Individualized attachments for research workers and managers, lasting from a few weeks to two years, in which they conduct research and learn new techniques. A somewhat similar category includes postdoctoral attachments in which individuals both learn and conduct research under the general guidance of a senior center researcher;

(c) Degree-related research of up to three years, related to the thesis requirements of a degree (usually masters or PhD) at a university in a developing or other country. Centers have a marked comparative advantage in training of this sort;

(d) "In-country" training in national or regional institutions, sometimes conducted cooperatively with former participants of training at centers, whose content is similar to that of category (a) group courses at centers;

(e) workshops, conference and seminars;

(f) library, information and documentation services; and

(g) publications of many kinds.

This chapter is concerned mainly with categories (a) to (d). Because these broad categories are defined in detail in different ways at different centers, it is not possible to be completely confident in over-viewing all activities in the system as a whole, but data have been assembled to show as complete a picture as possible.

9.2.3 Origins of participants

The centers host participants in formal courses from countries in all parts of the world. This category of training includes the largest number of people, and has served more than 14,000 individuals over the years indicated in Table 9.1. The largest number have come from countries in Africa, with Asian countries providing the second largest number. It is clear that the

Table 9.1 Number of individuals from different regions participating in group courses held by CGIAR centers[a]/

Center	Years	Number of participants from: Sub-Saharan Africa	Middle East North Africa	Asia	Latin America	Industrial Countries	Average no. per yr recently
CIAT	1968-84	3	2	52	984	0	90
CIMMYT	1966-84	307	258	410	558	31	130
CIP	1978-83[b]/	415	209	772	448	6	540
IBPGR	1973-82	23	39	246	62	26	130
ICARDA	1978-83	1	244	22	0	2	40
ICRISAT	1974-82	355	4	202	13	7	90
IITA	1970-83	1905	5	74	44	51	500
ILCA	1975-83	153	0	0	0	0	110
ILRAD	1972-82[c]/	339	0	32	7	63	25
IRRI	1962-82	68	7	1678	15	12	240
ISNAR	1981-83	307	11	97	121	0	180
WARDA	1973-84	1081	0	0	0	0	120
TOTAL		4957	779	3585	2252	198	2195

Source: Data suppplied by centers to TAC.

a/ IFPRI does not run group courses.
b/ Data include participants attending courses conducted by CIP regional staff in 32 countries.
c/ Data include 45 persons who were degree candiates or post-doctoral fellows.

centers tend to draw participants from the regions in which they are located, but that most also draw some participants from other regions. IRRI and IITA has been conducting courses over a long period and hence have large totals. Relatively few participants are nationals of industrial countries.

CIAT, CIMMYT, IITA, IRRI and WARDA all have trained over 1000 participants in their group courses over the years. The more recently established centers have trained fewer in such courses. IITA has one of the largest programs of training among the centers, reflecting the continuing strong demand in Africa for the technical type of training that can be efficiently provided in group courses.

IFPRI does not run formal courses and, indeed, does not have a designated training program. Rather, the approach taken in seeking to enhance professional skills in food policy analysis in this center with its modest number of staff, is to develop close and sustained collaborative arrangements with local and regional research organizations. Recent examples of such intense interactions are its relationships with Tamil Nadu Agricultural University and the Bangladesh Institute of Development Studies.

CIP has the largest number of participants in group training in recent years, but this number is not completely comparable with those shown for the other centers because it includes all of CIP's regional training participants. This is the principal category of group training by CIP and, by 1986, group training will no longer be provided at CIP headquarters.

The total number of participants sponsored for degree-related training is much smaller than the number attending group courses or individualized

programs at the centers, but at over 1400 is nonetheless a significant contribution (Table 9.2). While disaggregated data are not available from all centers, data for three show that 58 percent of participants were studying for master's degrees and 42 percent for PhD degrees. Thus, a conservative estimate is that the system has helped in the education of over 500 PhD holders from the developing countries. The distribution of participants across centers and regions shows that the largest group is from Asian countries and the second largest from Sub-Saharan Africa.

Among the centers, IRRI has been most active in sponsoring students for degree work, followed by IITA. Both of these centers have arrangements to send scholars to universities located close to their headquarters. Most other centers are more distant from universities and have sponsored a higher proportion of scholars for degree work in the industrial world. A proportion of degree-related scholars are nationals of industrial countries. These scholars and their sponsors continue to be active in pressing centers for training places and in seeking relevant experience at the centers in order to develop their own expertise and national capability in agricultural development, including expanding their capacity to provide staff for the centers.

Degree-related participants are, in most cases, associated with centers in order to use their research facilities and to receive guidance from scholars among the center staff who are immersed in research problems of current relevance to developing countries. Center staff are thereby much closer to such problems than are professors from industrial country universities and are more intimately involved in research than are many developing country professors.

Table 9.2 Number of individuals from different regions conducting research at CGIAR centers that was used toward advanced degree requirements. [a]/

Center	Years	Number of participants from: Sub-Saharan Africa	Middle East North Africa	Asia	Latin America	Industrial Countries	Average no.[b] per yr recently
IAT	1968-84	9	0	4	130	58	25
IMMYT	1966-82	19	18	9	26	20	5
IP	1978-83	0	4	5	67	3	10
BPGR	1973-82	13	12	20	5	4	10
CARDA	1978-83	0	13	2	0	5	10
CRISAT	1974-82	20	0	71	4	21	30
[illegible]	1970-83	172	0	7	2	81	65
	1975-85[c]/	28	0	0	0	0	15
[illegible]D	1972-82[c]/	28	0	0	0	5	15
RRI	1962-82	10	0	492	13	30	150
ARDA	1973-84	47	0	0	0	0	20
TOTAL		346	47	610	247	227	355

/ In most centers, master's and PhD scholars are included
/ Number in residence at the center during a year. Each participant typically takes 1 to 3 years to complete research activities at the center.
/ Total number at both levels for all regions is allocated as they were distributed in 1983.

About 3500 people from developing countries have participated in individualized training programs at the centers (Table 9.3). All of the nine centers shown have some facility for individualized training. This category of participant includes many different kinds of arrangements under which researchers gain some exposure to the centers. Tourist-type visitors are excluded from these data, even those with scientific interests who spend a day or a week at a center. These number in the hundreds per year at several centers. The data in Table 9.3 are intended to reflect those whose visits are sponsored by the center and who work on a program sanctioned by the center. It is, however, rather difficult to define this category clearly.

Post-doctoral training activities are not undertaken at all the centers, according to data gathered in the course of the TAC training study. Post doctoral participation is summarized in Table 9.4. IRRI has had by far theADP largest number but the activity has also been important at CIMMYT, IITA and ICRISAT. IFPRI does not, strictly speaking, consider appointments shown here as post-doctorals but rather as research collaborators. The largest number of post-doctoral participants have come from Asian countries, with quite a few from industrial countries and a substantial number from Africa.

9.3 General Assessment

Though people trained at centers usually represent a small proportion of all professional workers in agriculture in most countries, they are warmly praised and evidently have appreciated attributes. The countries wish for more training by the centers (section 5.4), though the types of training that they desire tend to change as development proceeds. Indeed, the training offered by centers does change over the years. It is consequently difficult

Table 9.3 Number of persons from different regions participating in individual research training programs at CGIAR centers

Center	Years	Number of participants from: Sub-Saharan Africa	Middle East North Africa	Asia	Latin America	Industrial countries	Average no. per yr recently
CIAT	1968-84	25	1	35	1265	73	135
CIMMYT	1966-82	176	211	350	409	52	70
CIP	1978-83	16	5	35	135	9	50
IBPGR	1973-82	2	5	16	5	6	5
ICARDA	1978-83	1	48	1	0	4	10
[illegible]ISAT	1974-82	3	5	9	2	0	15
[illegible]I	1979-84	0	0	0	0	0	5
[illegible]A	1970-83	212	1	17	6	17	25
ILCA	1975-83	44	0	0	0	21	30
IRRI	1962-82	28	6	405	14	25	100
TOTAL		507	282	868	1836	207	445

Table 9.4 Number of persons from different regions participating in post-doctoral programs at CGIAR centers

[illegible]er	Years	Number of participants from: Sub-Saharan Africa	Middle East North Africa	Asia	Latin America	Industrial countries	Average no. per yr recently
[illegible]IAT[a]/	1969-83	0	0	0	37	9	15
[illegible]IMMYT	1966-82	3	6	13	18	48	15
[illegible]RISAT	1974-82	9	0	32	9	21	20
[illegible]CARDA	1978-83	0	11	0	0	10	5
[illegible]ITA	1970-83	33	1	17	2	23	10
[illegible]LCA	1975-83	2	0	0	0	4	5
[illegible]RRI	1962-82	2	0	169	5	41	20
[illegible]FPRI[b]/	1975-83	14	0	51	6	0	10
[illegible]LRAD[c]/	1972-82	36	0	0	0	64	10
TOTAL		106	7	282	77	210	110

[illegible]/ Total is 38, allocated in proportion to CIAT's overall geographical distribution of trainees.
[illegible]/ Research collaborators at the professional level.
[illegible]/ Total number is 100, distributed across regions in proportion to the 1983 distribution.

for each nation to coordinate its responses to the offers of training that it receives from the different centers with which it cooperates. There is considerable demand for more higher degree training, which is costly.

In a number of countries, the scientific standards of the centers are so far ahead of those of the national agricultural knowledge system and institutions, that it is difficult for the countries to derive full benefit from the work of the centers. In other countries, only the degree training possibilities are perceived to be of real value.

Training at the centers has clearly strengthened agricultural research and the agricultural knowledge systems in many nations, and has played its part in the increases in output that many of them have realized. This is especially true where research is initiated on a commodity for the first time, as for example cassava and potato in many countries or where a country undertakes rapid expansion of a research area (see Feature).

In most cases, the centers select participants who have been nominated by governments or other employers in response to invitations from the centers. This two-stage process helps to maintain standards. Some degree-related participants are proposed by donors.

FEATURE: Researchers to Facilitate the Introduction of a New Crop

In the early 1970s Bangladesh was known by some observers as the agricultural "basket case" of the world. Massive food aid shipments were keeping the country afloat. Since then food aid has been halved, other cereals imports have been reduced by 25 percent and production of wheat, a new crop, has increased sharply. Situated on the threshold of the tropical worlds' wheat region, for a long time it was believed that wheat could not grow on a large scale in Bangladesh. But the events of 1965 to 1980 changed that perception: the area of wheat increased from less than 60,000 to over 425,000 ha and production increased to over 1.0 million tons (see Ch. 7). Training, with the assistance of CIMMYT, was a crucial part of the reason for this success.

In the middle 1960s after the first introduction of semi-dwarf wheat, senior CIMMYT staff reviewed wheat research and production in Bangladesh and recommended many changes including: (a) replenishment of seed stocks by importing varieties like Mexipak 69, and Super X from Egypt, (b) increased wheat prices, (c) appointment of a technical coordinator for the crop, (d) expansion of training, (e) initial concentration on selection rather than breeding, (f) additional research staff for off-station trials, and (g) development of seed certification. A training program for Bangladesh researchers was established with funding from the Ford Foundation, which periodically also reviewed the progress in wheat production.

Between 1968 and 1973, five Bangladeshi researchers were trained at CIMMYT in the crop improvement areas of plant breeding, pathology and production. In the next five years, an additional eleven persons were trained, seven in crop improvement. It was agreed that, with the support from the Ford Foundation, CIMMYT would train agronomists and farm managers for Bangladesh's agricultural research system besides subject matter specialists in wheat extension agronomy, and a total of 17 persons were trained in experiment station management and 19 in production agronomy between 1968 and 1984.

The expanded wheat research program started in May 1975. By this time the breeders, production agronomists and pathologist trained at CIMMYT were working in a team. A 1979 visit of CIMMYT researchers expressed concern over the fact that there was much greater dependence on a single variety, namely Sonalika than was really safe for the country. Selection for material more resistant to leaf rust was recommended and the multidisciplinary team necessary to implement this and other recommendations was able to undertake the work.

A proposal for the establishment of a wheat research center under the Bangladesh Agricultural Research Institute (BARI) was made in 1980. In all, 38 technical officers and 34 office and field assistants were provided for in the project. A resident advisor from CIMMYT was also requested. Informal training provided through frequent visits, consultations, and review of wheat work, supplemented the wheat scientists' own initiatives and efforts. Observations made by CIMMYT scientists, Ford Foundation staff and others, highlight the intimate rapport which existed between Bangladeshi scientists and their advisors.

According to former participants, the strengths of CIMMYT's training include the team spirit, the collegial atmosphere, emphasis on learning by doing and the professional values imparted indirectly by the behavior of senior scientists-cum-trainers. This is not to belittle the contribution of substantive skill-building in various disciplines.

The weaknesses, on the other hand, include the repetitive nature of experiments, incomplete coverage of the crop cycle and the lack of theoretical rigor in the curriculum. The need for relating training content to the specific problems and resources of developing countries was also voiced by many participants. There was a feeling that the analytical skills were given less importance than technical skills. A recently returned participant from CIMMYT mentioned that, while at CIMMYT, he did everything with his own hands whereas on return, he would start ordering others around. Short term training at CIMMYT also had the drawback of disqualifying the participants from going for a longer term of training abroad. Despite these limitations, some of the people who underwent training in the initial period showed remarkable commitment to wheat research.

Examples were given by participants of how they had utilized their skills after coming back. It is to the credit of the wheat research center at BARI that, in general, it is one of the most cohesive groups having an exceptionally cordial work atmosphere. Among some 49 researchers trainees, the wheat research program has lost only about 18 percent. The economics and farming systems areas have been left relatively under-covered, although a 1978 review recommended several activities that would have helped in this area.

The CIMMYT-CIDA program provided for training of four BARI scientists a year. The trainees in farm management courses were generally from the Bangladesh Agricultural Development Corporation (BADC) which played an extraordinarily vital role in seed multiplication and distribution. An innovative feature of the seed distribution program of BADC is a project in which farmers select a particular variety of their choice and are given a kilogram of seed in the pre-sowing period. The Federal Republic of Germany has been helping BADC through providing small machines that improve the quality of seed processing. But distribution points need to be opened in more areas. Equitable and efficient seed distribution, particularly on credit, is required for small-scale farmers.

Coordination within BADC with regard to crop-oriented programs may need to be reviewed and strengthened. There has also not been much effort to provide the potentially valuable links between the wheat research programs of India and Bangladesh. CIMMYT could possibly try to facilitate more cooperation.

In any research program, mobility of officials forms an important ingredient of learning as well as management. In the past, the reimbursement of travel expenses took as long as one year. At such junctures, sundry advances from CIDA/CIMMYT staff proved extremely effective in overcoming bottlenecks with regard to the travel of wheat scientists.

The reward system needed considerable strengthening and improvement. It is creditable that, while the wheat program received special awards in the earlier years from the government and from private voluntary organizations, there were not many staff members who had been given accelerated increments.

This is one area which continues to require attention by both BARI management and the public service authorities.

A National Wheat Research Center was established in 1982 and is now on its way to becoming a self-contained research nucleus focused on the site alloted for the purpose about ten years ago in N.W. Bangladesh. The role of wheat in the food basket of the next century in the country will be shaped from here.

Leadership is an important requirement in order that any research program take off. In Bangladesh, CIMMYT training played a crucial role in developing that leadership in the wheat program. The man identified as the leader of the wheat program was considered "too young" by the promotion committee in 1974 and was successfully promoted to principal scientific officer only after Dr. Borlaug of CIMMYT aware of his potential, wrote to the Secretary of Agriculture. The frequent visits, range of skills in which training was offered and team spirit engendered by the training program have been important in helping Bangladesh build an effective wheat research team.

END FEATURE

One consequence of the selection process has been the small proportion of female particpants in center training and fellowship programs. Although there are many factors influencing the situation, not all of them lie beyond the centers themselves. While it has not been possible to determine the exact percentage for each center, the eight percent female trainees out of the total number participating in IRRI programs between 1962 and 1981 would seem typical. The centers, in strict terms, have been engaged primarily in the development of manpower rather than human resources per se.

Some participants, initially in the transition to the new and different environment of a center, find it difficult and startling, but these reactions are soon overcome. The principal continuing difficulties are those of language. English is perhaps the principal language of agricultural science internationally and it is of most of the centers, but increasingly, centers are either providing some training in other languages or providing some language training to participants who work in other languages.

By their own reports and those to whom they report in national organizations, the effects on the participants of training at the centers are profound. The training experience increases knowledge and skills, employment of intellectual and physical labor, motivation, determination, purpose and confidence. Continuing contact with the center afterwards offsets isolation and helps participants to feel that they are valued citizens of the professional world.

The subsequent careers of participants suggest that, through these effects, most are able to serve research and development in their nations more effectively, even though many are promoted out of active research and some

move to commodities and disciplines different from those in which they were trained at a center.

Centers undertake training to advance their cooperative programs, to build national capability in research and other sectors of national agricultural knowledge systems, and to identify suitable candidates for their own staff and those of other advanced institutions.

Each center has links in training with many countries (up to 80 countries in some cases) and each of the countries contacted in the TAC training study has links with an average of about seven centers, which approach it separately, even if they are offering training in similar fields. This can lead to difficulties; for example, in studies of farming systems research methods. The centers are aware of these problems and have taken steps to lessen them. One recent concrete action was an agreement by all CGIAR centers operating farming systems training activities in Africa to keep one another informed of their respective courses and to carry out joint activities wherever possible.

Since the centers cannot meet all the perceived needs of the nations for training on topics in which they have comparative advantage, they promote "in-country" training. While these have some advantages, they also tend to dilute the benefits of being immersed in the atmosphere of an international center, which is available only at the center itself.

Centers simply cannot meet all expectations in respect of opportunities for thesis research for higher degrees - in which they have outstanding

comparative advantage. To do more in this direction they will need more staff, more accommodation and more money.

9.4 Advantages of Center Training

Since centers (unlike most other kinds of training institutions, including universities) are able to see their training participants as future continuing cooperators in research and dissemination, they do all they can to keep in touch with and to support them, and so increase the return on their investment of funds and effort in training. One center has set up a formal association of alumni; all send much of their published material to as many former participants as they can reach. Participants may be invited back to a center for workshops or to help in training others. These contacts are often very valuable to the former participants, not only for the information they convey but also because they imply continuing recognition and support. This helps to offset the sense of professional isolation, and the risk of obsolescence that is so great in the small and fragmented agricultural knowledge communities of many developing countries, particularly where foreign exchange for books, journals and travel is scarce. The annual report of a center may be one of the more important sources of information that a participant has. Indeed, this continuing contact and support may be one of the significant reasons why the participants have become a distinct and leading group in so many countries.

The leaders of national systems value training at the centers for a wide range of reasons, some of which were also given by participants themselves. Of course, most countries wish for all the training they can get, particularly if the costs can be met from external sources, but cost is probably not the

primary consideration. It is not always easy for a hard-pressed service to release staff for training, even if there are no external costs, or to guarantee participants jobs when they return.

Training by the centers has certain unique characteristics. It provides a continuing link, through former participants, with the centers and their work, and thus with the continuing advances of agricultural science generally. It improves the quality and performance of the participants, except in those rare cases where people may have been trained beyond the capacity of their nations to use their training. In these ways training by the centers has improved national agricultural research capabilities in many developing countries. It has also had effects on development, which are now considered.

Some nations have used training at the centers to strengthen the links between the different parts of the national agricultural knowledge system. When Indonesia began to cooperate with IRRI, research workers, extension leaders and district managers were sent to IRRI together. Before, they had not known or cooperated with each other. "They returned from IRRI hand in hand." Evidently, the authorities felt a need for research-related training in other areas of the agricultural knowledge system besides in research itself. Moreover, this soon led to "in-country" rice production and improvement courses in Indonesia, assisted by IRRI. The output of rice (supported by appropriate actions outside the domain of knowledge) began to increase; and it seems that the unit cost of the output decreased. Indonesia is today self-sufficient in rice.

The former participants encountered in the case studies were generally impressive individuals. Of course, they are a highly selected group, but it

became clear that the effects of training on most participants are profound. Many of the participants explained that the experience had changed them as people as well as professionals. They spoke not only of advances in knowledge and technical skills, but also of dedication to both intellectual and physical work, motivation, determination, purpose and confidence. Many, particularly those who had attended production courses, had become trainers themselves, and had organized such courses in their own countries.

These assessments of the effects of training at a center were consistently confirmed by supervisors in most of the nations - often using virtually identical language. A few, while recognizing these general effects, suggested that work at a center could accustom people to techniques and equipment that could not be used or were not available when they returned home, but such remarks were sometimes colored by experiences with students who had followed higher-degree courses in universities in industrial countries. In the broader perspective, the relative exclusion of women professionals from participation in center training and, in turn, from emerging agricultural knowledge systems can have only a deleterious effect, perhaps especially though not solely where women's participation in food farming and marketing are highest.

The center participants include many leaders in agricultural science and development, clearly different, in many countries, from the majority of professional workers in those fields. Of course, many developing countries have produced distinguished leaders in other ways but, even in those cases, the CGIAR participants significantly add to their human resources for agricultural science and development.

Many reasons were given for these effects (section 5.4). One of the most general was that much of the experience was practical, particularly in production and breeding courses. To work with a crop in the field from sowing to post-harvest operations, or to learn a specialized technique in the field or laboratory, turns theoretical knowledge, acquired from reading and listening (from "the study of agricultural science as a branch of literature" as one senior observer remarked) into practical competence and understanding. Such an experience provides a basis for genuine confidence; and it makes for far more effective research workers. Few research workers seem able to do effective research on a crop unless they also know how to grow it themselves.

9.5 Changes in Types of Training

Given the data at hand it is not possible to quantify all the trends that have occurred over time in the training offered by the centers but several are evident. One is the trend toward a lower proportion of training in production courses in favor of a higher proportion of training in research methods. A second is the trend toward a greater proportion of total training activities outside the headquarters of the center, or so called "in country" training.

Figure 9.1 shows the increases that have occurred in number of in-country training participants of just one center over the past several years. This kind of training with cooperation between national programs and the centers is, of course, essential and must clearly be encouraged, until a nation's agricultural knowledge system is strong enough to manage training for itself. Indeed, it must be an objective of the centers to hasten the day when in-country training becomes in-country business. But in-country training must

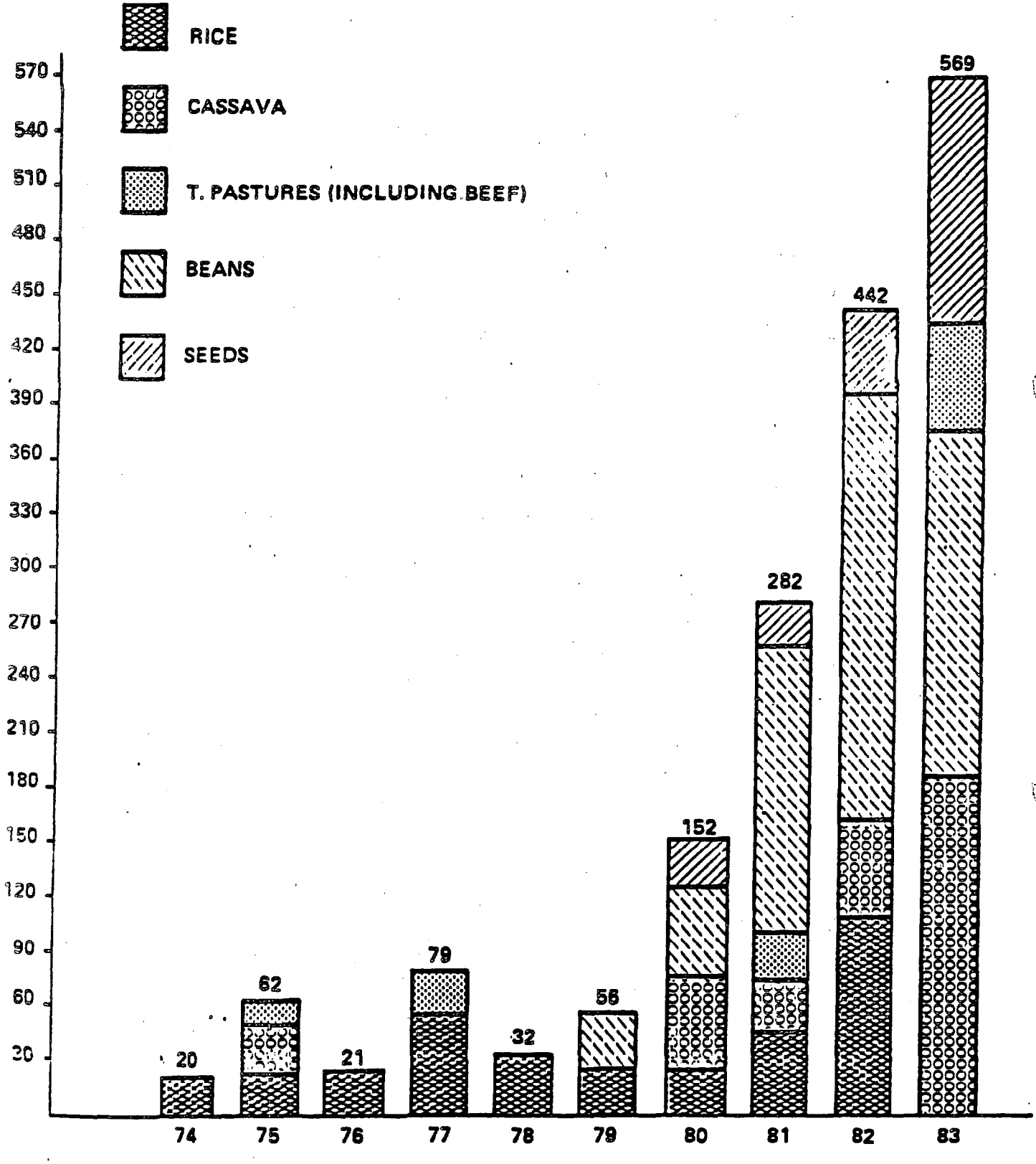


Figure 9.1 NUMBER OF PARTICIPANTS OF IN-COUNTRY TRAINING COURSES ASSISTED BY CIAT 1974 – 1983.

often dilute some of the special effects of training at a center that were considered above. The "call system" (by which trainers from a center respond to a call from a country to visit training participants at critical stages of the crop cycle) and the systematic training of trainers to create domestic capacity are means of offsetting this potential loss. Some centers support in-country training by bringing the in-country trainers to headquarters from time to time as visiting scientists or as trainers. All support the in-country trainers with senior professional staff.

The contributions of the centers to degree-related training have been modest, but the centers are potentially able to offer unique opportunities for advanced training, on topics important for developing countries, and in appropriate environments, and the graduate student participants have made valuable contributions to centers' programs. The centers are held back from doing more in this area by lack of funds and by the constrained senior staff time required to provide adequate supervision, particularly when theses have to be written.

They cannot fairly relinquish their tasks to their university partners, unless these partners are involved in the supervision of the work as practical collaborators in the centers. But for many academics, and for some centers, this route offers difficulties. In some centers, many of the scientific staff are dedicated to their research responsibilities, and not all of them see the supervision of higher degree candidates as a natural extension of these tasks. This is a question of attitudes, from the senior management down, and it is unlikely to be resolved solely by including academic supervisory tasks as part of the contractual responsibilities of center scientists. If the centers are to provide more degree-related training, as some believe they should,

additional posts, additional accommodation and additional funds will be needed. In some cases it may be useful to appoint experienced academics, where possible from the cooperating universities, as sabbatical workers whose duties include academic supervision, and some appointments have indeed had this character in the past. Post-doctoral researchers may also assume part of the task, as they do at ILRAD. The centers are not universities, but they need some characteristics of university institutions if higher degree work is to be increased.

In many developing countries there are substantial plans to support higher education, but few of these plans take account of the possible contribution of the centers. Some of the funds to be applied come from sources earmarked for bilateral technical cooperation in education and training, rather than from sources intended for multilateral support for agricultural research. It should be possible to resolve this emerging problem - particularly if the recipient countries themselves insist that the centers be used for higher degree training in appropriate cases.

9.6 Coda

* The CGIAR system recognizes the need for developing countries to improve their own capacities to conduct research and is engaged in many different efforts to improve that capacity.

* More than seventeen thousand people have been trained at the centers.

* Former participants in training provide some of the most important channels of communication between the centers and the national programs.

* The direct costs of training and conferences to enhance human capital consume about eight percent of the core budgets.

* CIAT, CIMMYT, IITA, IRRI and WARDA all have trained over 1000 participants in their formal courses. IITA has one of the largest programs for such training, reflecting the continuing strong demand for technical training.

* The system has helped in the education of about 500 PhD holders and about 900 master's holders, but not all senior scientific staff of centers see the supervision of higher degree candidates as part of their responsibilities.

* About 3500 people from developing countries have participated in individualized training programs at the centers.

* People trained at centers are generally warmly praised by their supervisors and evidently have special value to their countries. The countries wish for more training by the centers though the types of training they desire tend to change as development proceeds. There is considerable demand for more higher degree training.

* Training at the centers has clearly strengthened agricultural research and the agricultural knowledge systems in many nations, and has played its part in the increases in output that many of them have helped to realize.

* The training experience increases knowledge and skills, employment of intellectual and physical labor, motivation, determination, purpose and confidence.

* The relative exclusion of women professionals from participation in center training and, in turn, from emerging agricultural knowledge systems can have only a deleterious effect, perhaps especially though not solely where woman's participation in food farming and marketing are highest.

* Since the centers cannot meet all the perceived needs, they promote "in-country" training.

* Centers cannot meet all expectations for thesis research for higher degrees. To do more in this direction they will need more staff, more accommodation and more money.

* Countries value training at the centers for a wide range of reasons. Training by the centers has certain unique characteristics. It provides a continuing link, through former participants, with the centers and their work. It improves the performance of the participants and the quality of their work.

* There is a trend toward a lower proportion of training in production courses in favor of a higher proportion of training in research methods. There is also a trend toward a greater proportion of total training activities outside the headquarters of the center, so called "in country" training.

10 NATIONAL RESEARCH CAPACITY

10 NATIONAL RESEARCH CAPACITY

10.1 Introduction

The growth of national agricultural research systems and international research centers is a mutually reinforcing process. The international centers were built on scientific knowledge generated by national systems in industrial and developing countries. They assembled germplasm collections from national programs and others, and systematically built networks upon them, becoming stronger as the national programs which participated in them produced better materials. They hired research staff from universities and national programs of industrial and developing countries. The national programs, in turn, have gained much from the centers. This is to the benefit of the centers, the farmers and others. International centers cannot have much impact on farming unless there are researchers to do adaptive work at the national level and extension workers to exchange ideas with the farmers. The national systems develop technology for farmers using materials supplied in part through the international networks, together with centers' and others', methods and ideas. Without the capacity to adapt technical components to local conditions, there would be severe constraints to using center-developed technology because it would fit relatively few situations well.

The aggregate growth of national research systems over the past quarter century has been rapid, but some important activities cannot readily be carried out by some national institutions, and many national programs still have important weaknesses. It is in some of these areas that the international centers have played, and will continue to play, an important role. The international testing and movement of germplasm can be handled more

effectively by an international organization than a national research program. Establishing and supporting international networks of research workers is another type of activity that may often be done best by an international center. Many developing countries seemingly are still not investing sufficiently in agricultural research. Some systems lack sufficient human resources to carry out effective research programs and endure institutional inefficiencies that prevent them from making good use of available resources.

There are three principal ways by which the international agricultural research centers can influence national research capacity. First, is by the education of policy makers and the public at large on the productivity and the importance of research, including studies of the returns to research and the benefits generated by research in other countries. Second are projects to build national research institutions. These include special projects such as IRRI's long-term work in assisting in the development of the Bangladesh Rice Research Institute and CIP's work to assist PRECODEPA in Central America, as well as most of the work of ISNAR. Third are the regular services which the centers provide to the national systems, including collaborative research, training, storage and distribution of germplasm, research methods, the findings of basic research, bibliographic services, publications, conferences and so on.

All the centers have committed substantial resources to assisting in the development of national research institutions, both in direct and indirect ways. The need for such development was considered to be so important that, in 1980, the CGIAR established ISNAR. Its constitution states that ISNAR's "ultimate goal is to enable developing countries to plan, organize, manage and execute research more effectively." This chapter is devoted to discussing the

contribution of the CGIAR system to building national research capacity, but many of the support services of the centers that are discussed in other chapters are not repeated here.

The impacts on the national research systems fall into three major categories: (a) impact on aggregate national budgets for research: (b) impact on the allocation of research resources by commodity, project and discipline: and (c) impact on the organization of the institutions for research and technology transfer. The latter category includes such things as changes in institutional structure, improved research planning and management, new research methods, and improved linkages among research, education and extension institutions, both domestically and abroad.

10.2 Financing National Research

The existence of the CGIAR has affected the level of finance available for national agricultural research by its demonstration effect as well as by its effect on the expectations of national decision makers. The publicity surrounding the green revolution raised the expectations of decision makers in many developing countries about the potential benefits from agricultural research (chapter 3). Economic analyses of the consequences of new technology, including impacts on income distribution and nutrition, helped to quantify the returns to research and to generate support for national agricultural research. Collaboration with the centers raised the productivity of research and helped governments to see that there could be high returns to research in the future. The publicity and productivity effects not only influenced national research systems, but also helped to persuade foreign donors that agricultural research was a productive investment.

Some observers have taken an opposite position - suggesting that a rational national program would neglect domestic research capacity by "free-riding" on the centers, especially when there is one located within the boundary. There have also been suggestions that the international centers attracted financial resources from donors that may otherwise have been invested directly in the national systems.

Evidence collected in the country case studies generally supports the former view. Scientists who were active in Asian national research systems in the 1960s say that the green revolution convinced many national leaders that research could really accomplish something significant. The Ford Foundation representative in Pakistan planted CIMMYT varieties on the fields of President Ayub and several of his top advisors. The yields on those fields assisted in bringing home to the government that wheat research would be a good investment. Senior officials in Bangladesh (then East Pakistan) travelled on an IRRI-sponsored tour of the Philippines and Japan that effectively demonstrated the potential of IR8 and similar varieties, and of agricultural research more generally.

The Rockefeller and Ford Foundations have long been concerned with world food problems, and they took strong leads in supporting agricultural research addressed to their solution. USAID started to support agricultural research in the late 1960s, partly in response to public concerns about the food crises of Asia. The early successes of the centers clearly influenced USAID's decision to invest in national research. Over the past three decades, several donors responded to the food crises in various parts of the developing world

with, inter alia, additional support for research. The performance of the food production sectors of Asia has clearly justified that support.

As yet, there has been much less evidence of research benefit in Africa, where the investments were made later and the base of commodity-specific knowledge was generally lower but, as shown in chapter 3 there has been significant growth in domestic systems. IITA became involved in root crops improvement in Cameroon in 1977. This involvement has led to a greater appreciation on the part of government of the value of research and development and has resulted in about a five-fold increase in government expenditure on root crops improved between 1978 and 1984. The Cameroon National Root Crop Improvement Program has been strengthened to the point that it is now self-supporting.

Data on the stability of funding of research in national systems are even more sparse than they are for recent levels of funding. An interesting hypothesis that could be addressed at some data-richer stage is that stability of funding for the centers has positively influenced stability of funding in national research systems. Authorities from the developing countries have observed in this study that erratic funding has produced national research that is perfunctory, half-hearted and replete with half-completed and abandoned projects, and may have been more damaging to research productivity than the inadequacy of the general level of funding.

10.3 Research Priorities

10.3.1 Commodity

A key issue for any research system is the allocation of research resources between different commodities, disciplines, institutions and projects. Allocation between different commodities has received much attention by analysts generally and, within the CGIAR, by TAC in particular. The centers were in part a response to a perception that too little research was being done on food production and consumption. Their activities have, it seems, indeed induced more national research on the key food crops (see section 10.9 below).

The inducement effect is clearest where counterpart research programs did not exist prior to center involvement. For example, many countries had no organized research program on cassava or other root and tuber crops until they came into contact with IITA and CIAT. A total of 23 national root and tuber crops improvement programs have been developed in Africa since 1971, stimulated by IITA's work on cassava, yams, sweet potatoes, and cocoyam. Table 10.1 shows some aspects of CIAT's participation in a number of new cassava research programs. Only India had a national cassava research program before the centers' programs were established. Wheat research programs in the Philippines, Thailand and Burma have been analogously stimulated by CIMMYT's tropical wheat research.

Collaboration has led to increases in the size of existing programs in many countries. Table 10.2 shows that, in Bangladesh, rice research investment was considerably smaller than that for jute research during the early 1960s. By the 1970s, Bangladesh policy makers were investing much more

Table 10.1 Some links between national cassava research activities and CIAT

	CIAT trainees	Receiving genetic material from CIAT[a]/	CIAT lines released or grown	Visits by CIAT staff since 1977
Thailand	24	S	Yes	18
Indonesia	12	S	No	8
Philippines	11	S	Yes	18
Malaysia	14	S	No	10
China	0	S	No	2
India	5	S	No	11
Brazil	94	S	Unknown	34
Paraguay	3	S	No	6
Bolivia	5	No	No	6
Peru	10	S	No	7
Ecuador	12	No	Yes	18
Colombia	86	E	Yes	NA
Venezuela	14	No	Yes	2
Panama	7	M	No	6
Costa Rica	9	Np	Yes	12
Mexico	31	SM	Yes	27
Haiti	4	No	Yes	6
Dominican Republic	20	No	Unknown	17
Cuba	12	S	Yes	14
Guyana	4	No	No	1

a/ M = Meristems, S = Seeds, E = Stakes.

in rice research, and a few donors enabled the country to obtain the foreign exchange needed to build its capacity for rice research.

The analysis of commodity research expenditures for 25 developing countries described in section 10.9 below shows that, during the 1970s, there was a strong positive association of national commodity research expenditures with research expenditures on the same commodities by the centers. That is, national research investments increased more rapidly for commodities being researched by CGIAR centers than for "non-center" commodities.

Young national systems often respond strongly to the activities of the centers, rapidly building research capacity in a particular area, perhaps leaving behind their capacity in other crops or ecologies. For example, Syria's research expanded about three-fold between 1978, when it handled 144 projects, and 1984 when it had 343 projects (El-Akhrass 1985, p.18). Research on field crops corresponding to ICARDA's activities made up about 42 percent of the projects in 1978, while by 1984 it made up 73 percent.

But with development, national priorities are reasserted. The experience of Bangladesh again is instructive. As noted, Bangladesh greatly expanded its rice research activities between 1965 and 1980. During the late 1970s, national authorities and donors became aware that technological development for other crops was falling behind, and a major effort was made to strengthen another institution, the Bangladesh Agricultural Research Institute, with responsibilities for research on other major food crops. Expenditures on other food crops far exceeded those on rice by 1980 (Table 10.2). It could be argued that IRRI's influence initially "distorted" the national priorities in this case. Alternatively, however, the argument can be

Table 10.2 Allocation of agricultural research expenditures in Bangladesh (Tk M current)

Crop/ Institution	1950-[a] 1960	1960-[a] 1965	1967	1974	1979	1980
Rice	.2	.3	1	7	28	40
Other food crops	.2	.2	n.a.	12	77	129
Jute	.2	.5	2	2	10	11
Tea	0	n.a.	n.a.	2	6	5
Sugarcane	n.a.	.1	.1	4.5	10	14
BARC	0	0	0	n.a.	5	11
Livestock	n.a.	.6	.3	2.8	n.a.	n.a.

a/ Annual average.

Source: Pray and Ahmed (1984).

made that the successfully functioning rice research institute was a strong stimulus for the establishment of the needed national capacity for research on other crops.

Some cases have been cited as examples of centers "crowding out" local research. In particular, countries that host centers face particular challenges in determining appropriate domestic institutional responses. IRRI research appears to have been a partial substitute for national rice research in the Philippines, in that investment in rice research would probably have increased more rapidly in the absence of IRRI. The Philippine Council of Agricultural and Resources Research and Development (PCARRD) had, until recently, decided that rice was a priority II crop and, as such, allocated it fewer resources than for priority I crops such as maize. The University of the Philippines Institute for Plant Breeding, the major institution for crop improvement, until recently undertook no rice research, and the University's Department of Agronomy has done only a little. The expressed view of the leadership of the Philippine Ministry of Agriculture is that virtually all of the rice research that is required is available from IRRI. Two experienced Philippine rice breeders work for IITA and IRRI. The net effect is a rice breeding program at the University of the Philippines that is probably weaker than it was in 1970, but the presence of IRRI provides a total rice research effort applicable to the Philippines much larger than it would be in its absence.

Rice research in Colombia has been cited as another example of centers replacing national programs (Trigo, Piniero, and Sabato 1983). The evidence here is not so clear, however. The share of crop research resources going to rice increased from five percent in 1964 to nine percent in 1969, and

remained constant at that level to 1983. There appears to have been a substantial shift in research priorities in recent years from irrigated lowland rice to upland rice. There is also evidence that the quality of some of the rice research program may have declined due to the departure of the most experienced rice breeders to the centers.

The pull of research resources toward food crops which the centers have stimulated seems generally to be a movement toward a more efficient allocation of resources, especially because food crops were so neglected by colonial governments. Some of the specific commodity programs instituted with center stimulation have attracted comment because they absorb significant research resources on commodities which make up a small share of the value of output. For example, Table 10.3 shows the increase in researchers on potatoes in the PRECODEPA countries. The tropical wheat research programs in the Philippines and Thailand, and the maize research program in Bangladesh are other examples.

Clearly, there are cases where the centers have effectively encouraged countries to increase their research on food crops. It is useful to remember, however, that there are a number of large national research systems and some small ones in which research by the centers has apparently had very little effect on research priorities. For example, in Brazil there has been a gradual shift of resources toward export crops. On balance, the degree of induced distortion, for the developing countries as a whole, has probably been worth whatever negative effects it might have had because of the stimulation it has given to entire national systems.

Table 10.3 Personnel of national potato programs before PRECODEPA and at present

Country	1977/78			1983/84		
	Full	Part	Total	Full	Part	Total
Mexico	2	2	4	8	10	18
Guatemala	2	2	4	11	20	31
Honduras	1		1	3	8	11
Costa Rica	1		1	6	3	9
Panama	1	1	2	4	5	9
Dominican Republic	2		2	12	5	17
	9	5	14	44	51	95

Note: All salaries are financed entirely from the respective national budgets.

Source: CIP (1984)

10.3.2 Research priorities within commodity programs

The examples of the centers and their specific successes have influenced the structure and goals of many national commodity programs, some in relatively subtle ways, others more overtly. Even before IRRI was established, some rice research programs of Asia had absorbed the lessons from Japan, Taiwan, and Korea that fertilizer-responsive varieties could raise yields. Under the auspices of the FAO, they started the Japonica-Indica crossing program in 1954, with the aim of developing varieties responsive to fertilizer. The production of semi-dwarf rice varieties such as IR8 shifted national researchers' attention away from Japonica-Indica crosses during the 1960s. The semi-dwarfs were tested under higher fertility levels and fertilizer responsiveness was adopted by some breeders as a breeding objective. Indian authorities report that there was a shift of resources from unirrigated to irrigated rice research. After IRRI started to screen nurseries without insecticide protection, many national programs followed suit. The national rice research program in the Philippines also started to breed semi-dwarf varieties for irrigated conditions, but soon decided to let IRRI work on lowland irrigated rice while it concentrated on upland rice.

CIMMYT's emphasis on breeding maize varieties rather than hybrids had a significant impact on many maize research programs in Latin America and Asia. For example, the Burmese maize breeders had concentrated unsuccessfully on hybrids until they started working with CIMMYT. Now they are directing their breeding efforts almost entirely to the production of composites rather than hybrids.

In other cases there were major changes in many parts of the research program. Research on potatoes in Bangladesh changed dramatically. Instead of

selecting only from the best-yielding Dutch varieties, the program started selecting from the collection of local varieties and tropical varieties from CIP. Completely new research programs, including diffused light storage, true potato seed and a clean seed production program, were also added.

10.3.3 Solving farmers' problems

Perhaps the most important impact of the centers on research priorities has been the orientation of researchers toward solving farmers' problems -- oftentimes under the banner of farming systems research (see chapter 16). This shift of research efforts is probably impossible to quantify, but national research and administrative people who have worked with the system over a lengthy period persistently point to this as one of the most important contributions of the centers. The researchers in the centers provide prestigious role models for national research workers which may often be for the good. The centers provide reinforcement and rewards for practical work by their national partners in the form of attendance at conferences and publications of the results of applied research. The training programs at the centers also stress applied research in the field. To quote the then head of EMBRAPA: in the past "most of the research in Brazil ... was not oriented to the farmers' problems...This [the idea of working on farmers' problems], in my opinion, is much more important than the cultivars because...you are teaching us how to fish instead of giving us the fish." (Alves 1984, p. 123).

The Nile Valley project of Egypt and Sudan in which ICARDA is centrally involved is a good example of encouraging national scientists to work on farmers' problems in farmers' fields. This effort, aimed at testing technology to increase yields of faba beans on farmers' fields, has provided an opportunity for research workers from the two countries to conduct field

research under farmers' conditions, to interact with each other and with international scientists.

The fact that centers have such little direct contact with extension services means that any desirable influences on research systems are not readily replicated in extension or in the linkages between research and extension systems which, in many countries (and especially in Africa), remain tenuous and ineffectual.

10.4 Institutional Structure

The centers have been encouraging national research organizations to use their model of interdisciplinary teams working on the practical problems of farmers since they were established, and have had considerable success in popularizing the model. However, the time and effort they devoted directly to institution building was judged to be insufficient for building national research programs at the necessary rate, and ISNAR was established to focus specifically on that need. Thus, the centers have had informal as well as more formal influences on the institutional structure of national programs.

10.4.1 The centers as models

A number of national institutions have used the structure of the centers in designing their own activities. EMBRAPA, the Brazilian agricultural research corporation, established a series of commodity institutes organized in multidisciplinary teams as the basic structure for its new national agricultural research system. This structure was adopted on the basis of what Brazilian scientist had read about the centers and seen in visits to them. Bangladesh and Indonesia have built rice research institutes modeled on IRRI

with the assistance of IRRI personnel stationed in the countries. ICTA in Guatemala was organized following the farming systems research model developed by CIMMYT and others. In the case of several crops where little had previously been done - such as cassava and potatoes in many countries - the centers helped bring scattered researchers together into structured interaction for the first time.

IITA has influenced considerably the organization and management of agricultural research in Africa. The multidisciplinary approach of IITA has been adopted in many national research programs in Africa, particularly those in Cameroon and Nigeria. Farming systems research is, in Nigeria, an innovation which took its roots from the IITA Farming Systems Program. This has influenced the organization of research in all the national agricultural research institutes (Okoro and Onuoha, 1985, p.75), and as well, Nigerian research institutes now organize regular in-house reviews.

In addition to countries which copied entire commodity research programs, many have imitated parts of commodity programs. An example of this is the Indonesian Genetic Evaluation and Utilization program (GEU) that was established in 1975. It was formed in response to the need to coordinate rice breeding activities in order to respond better to outbreaks of brown planthopper. It took both the name and the institutional structure of IRRI's GEU program.

In contrast to the organization of a single commodity research program, ISNAR was set up to help improve the working of national research systems as a whole. ISNAR assists countries in the identification of needed changes and in promoting the needed changes by providing necessary information for decision

making, pointing to opportunities, helping to design alternatives, and helping to lower the costs of institutional change by facilitating donor support of the process of change.

ISNAR has recommended institutional and organizational change in 12 out of the 18 countries where its review and planning missions have been completed. Since it has tried to meet the specific needs of those countries, the proposals suggested have varied widely. New organizations have been proposed to improve control over resources and program matters, to facilitate more effective management of available resources, and to improve interactions with policy-making bodies in the Dominican Republic, Costa Rica, Kenya, Ivory Coast, Guyana and Papua New Guinea. ISNAR advised Sri Lanka and Malawi that they could improve their resource allocation and program coordination through the creation of research councils or their equivalent. Madagascar and Rwanda were advised that they could generate improved relations with client groups and increased accountability of research activities through new governance mechanisms for existing institutions. Changed internal organizations to improve management possibilities and the more effective use of resources constituted the core of proposals in Fiji and Morocco, and have been part of the broader institutional recommendations in the Dominican Republic, Rwanda and Madagascar. Reduction in the number of stations and rationalization of research station networks has been proposed as a way of improving the use of available resources and the effectiveness of research efforts in Madagascar, Fiji, Western Samoa, Rwanda, and Morocco.

Feature: The Dominican Republic experience

The experience of the Dominican Republic is an example of ISNAR's successful assistance to a system in the process of institutional change. ISNAR involvement in the Dominican Republic started in 1982 when the Secretary of Agriculture invited ISNAR to organize a mission to review the government research system. A team of six people visited the Dominican Republic in early 1984. They worked with a team of local counterparts to develop a proposal to create a new semi-autonomous agricultural research institute in place of the research organizations that were under the Ministry of Agriculture at the time. This new institution would have the power to promote people on the basis of merit, and the flexibility to use its budget for effective, high-priority projects. This would increase the productivity of the system by increasing the motivation of research staff and providing the more productive research workers with more resources.

The next step was to develop a proposal that was acceptable to most interested parties in the agricultural sector. Three areas of action were involved: first, the proposal had to be accepted by the research system and the Secretary of Agriculture; second, because of the high rate of turnover in top levels of the research system, a process of information sharing was required to obtain the commitment of the newcomers: finally, as discussion progressed, new interest groups such as universities, extension organizations and donor agencies had to be involved. These tasks were carried out by the local working group, with ISNAR participation through periodic visits to provide advice on specific issues. As the decision to implement the new

institution seemed imminent, ISNAR, at the request of the Secretary of Agriculture, placed a permanent consultant in the country to work full time with the working group.

The last step was to convince the legislature (a) that research was a valid part of the solution to the food problems facing the country and (b) that the creation of the new organization was the appropriate means of achieving an effective research organization. Two instruments were used to work with the legislature. The working group and other officials from the Ministry of Agriculture contacted lawmakers on an individual basis to brief them on the nature and objectives of the new research institute. The second instrument was a national workshop to discuss the pros and cons of the initiative to create the new institute. The participants included the agricultural committees of the House of Representatives and the Senate, the present and several past heads of research and extension and other influential people connected with the agricultural sector. The workshop relied heavily on case studies constructed so as to highlight the problems of the present structure of agricultural research and the reasons why the new organization should be more effective. ISNAR helped to organize the workshop and provided materials in the form of case studies, and members of the original missions participated as resource persons.

The workshop proved to be highly successful. The result was the tacit support of the agricultural committees of both the House and Senate, and an agreement to the modifications that should be made in the proposal sent by the President to Congress.

Implementation of the above proposals has followed a different pattern in each case. Implementation is proceeding with full ISNAR participation in several countries: e.g., the Dominican Republic, Kenya, Fiji, Madagascar, and Rwanda. In others the proposals have been accepted and are being implemented essentially through local initiative with little or no involvement on the part of ISNAR: Papua New Guinea, Western Samoa, and Guyana. Finally, there are one or two where no significant action is taking place, for example, Costa Rica.

The extent of implementation is in part due to the timing of the original missions and in part due to the particular characteristics of the political and administrative processes of the countries involved.

10.4.2 Institutions for germplasm work

The IBPGR's basic function is to promote and coordinate an international network of genetic resource centers to further the collection, conservation, documentation, evaluation and use of plant germplasm and to increase the diversity of germplasm available to plant breeders (chapter 12). IBPGR has been responsible for the development of new national genetic conservation programs in about 50 countries and the development of national genetic resources committees in 25 countries. It has assisted national programs to develop their germplasm collection through grants for collection of materials and for storage facilities, training in the collection, characterization and preservation of genetic materials, conferences on the latest methods of preserving germplasm, and data banks on germplasm availability. This assistance has been channeled to national institutions and has served to strengthen their capacities to carry out such work.

10.5 Research Planning and Management

10.5.1 ISNAR

The objective of ISNAR's management training activities is to strengthen the managerial capabilities of agricultural research officials. More than 130 individuals, most from Africa, have participated in research management training programs. ISNAR has also undertaken in-depth surveys of management training needs in Cameroon, Sudan and Zimbabwe and will use the results of those surveys to develop a better focus for training and case studies for further courses.

In response to problems that came up in many of its country reviews, ISNAR has devoted considerable attention to developing professional organization and training plans for several national research programs. ISNAR worked in Kenya with the National Council of Science and Technology and the Ministry of Agriculture, to identify the characteristics of current human resources in agricultural research. This analysis led to a national staff development plan for agricultural research and to a plan to strengthen the Faculty of Agriculture at the University of Nairobi. The Service has cooperated with the Kenyan authorities in the formulation of both plans. ISNAR has provided staff inputs in Thailand to an interagency commission investigating conditions of service for personnel in the Department of Agriculture. The task of this commission is to recommend procedural changes that will encourage larger numbers of Department personnel to serve at research centers outside Bangkok. On the basis of the ISNAR work, the

commission has moved to explore revised recruitment standards and new career paths for Department personnel.

ISNAR has seemingly been cautious in collecting or making data available for discussion in relation to strengthening national research and extension institutions' capacity to reach and serve women farmers. In a number of countries with which ISNAR has been working, women are major food producers in their own right (e.g., Kenya and Papua New Guinea) or form a significant proportion of agricultural research and extension personnel (e.g., Thailand). Both cases may pose special problems of human capital enhancement and require attention in proposals for structural reorganization and planning reforms.

10.5.2 ILCA's role in providing data processing

One of ILCA's more important products to date has been the analytical services that it provides to national agencies which have large data bases on animal production, but lack the human skills or computers to appraise such data. National researchers analyze the data at ILCA with the assistance of ILCA staff. The results of these analyses allow national agencies to make informed decisions about the continuation, enlargement or reorientation of their livestock development programs. The results have also been used to assist in the preparation of livestock projects funded by major donors and lenders such as the World Bank.

The need for this kind of information is clear: "Livestock numbers, yields and, a fortiori, management practices, in traditional herds are usually shrouded in even denser veils of ignorance (and, worse, of self-confident assertion) than apply to smallholder crops data. Improvement upon the scandal of agricultural and food statistics in most of Sub-Saharan Africa is a

necessary, and inexpensive, precondition for significant policy improvement and therefore for agricultural research design..." (Lipton 1984, p.30).

10.5.3 On-farm trials and research priorities

On-farm research programs have been promoted by the centers and others and are being used by national researchers as an input into the research planning process. One of these systems is used at ICTA in Guatemala where on-farm research dominates the whole research system. Farming systems research is viewed favorably in Panama, and in several E. African countries where it has had considerable impact in influencing research styles and orientation (chapter 16). There are also examples of much less formal types of interaction between farmers, plant breeders and social science staff, helping to set new priorities. One example relates to the work of CIMMYT staff in N. India. The Pantnagar University maize research program integrated farmer surveys and on-farm trials into its work. This led to revision of the extension recommendations on pesticide and fertilizer applications. The blanket recommendation that farmers spray thiodan to prevent stem borers was withdrawn and the recommendation for N, P, and K was reduced from 80:60:40 kg/ha to 80:0:0 kg/ha. Research priorities were changed considerably. Research was increased on appropriate plant populations, and on leaf spot. More use was made of local germplasm. Concentrated research activity was shifted from Pantnagar, which was atypical of the major maize growing regions, to Bulandshalkur in the middle of the U.P. corn belt (Biggs 1983).

The survey of yields of deep water rice by personnel of the Bangladesh Rice Research Institute Economics, Farming Systems and Deep Water Rice programs provides a further example. They found that the actual yields of

many farmers were higher than the goals set for the Institute 's current breeding program, and so redefined the yield targets upward.

10.5.4 Experiment station management

CIMMYT's station managers have worked with people responsible for experiment station management in more than 25 national programs. Eight years ago, CIMMYT introduced a formal training program offering practitioners an opportunity to share some of its experience. Techniques evolved from this work are now being applied in Ecuador, Tanzania, Pakistan, Turkey, Thailand and the Philippines.

10.6 Research Methods

The centers have played an important role in enhancing research methods in developing countries. Many of the methods were innovated at the centers but many others were first developed elsewhere and spread by the centers through their training programs and outposted staff. Among the large number of these methods now in use in developing countries, some representative examples are presented.

One of the most important new research approaches which centers have developed and popularized is the "high volume crossing approach" — the procedure of making a large number of crosses and exposing them to heavy pressure from relevant pests and diseases. Heretofore the standard plant breeding approach featured a few, carefully chosen crosses which were grown under protected, experiment station conditions. Now the many-crosses-and-heavy-pressure approach has become the convention for most small grains programs around the world.

The techniques that centers have developed to screen lines for disease and pests resistance are among the most commonly mentioned new techniques in the country case studies. Most of the centers have developed such techniques. ICRISAT's technique to screen pearl millet for downy mildew, ergot and smut in the same generation is one such example. Centers have also developed new ways to multiply existing pests in order to put heavy selection pressure on crops. For example, techniques for the mass production of downy mildew inoculum were developed by the Philippine and Thai national programs with CIMMYT collaboration. Techniques for inducing heavy pest pressure are, of course, used only where a particular pest already exists in an ecology. Having cooperating researchers in different ecologies permits evaluation of reactions to pests that do not exist in the home ecology of a researcher.

The centers have also developed important laboratory procedures for testing grain quality. CIMMYT methods for testing the milling and baking qualities of wheat have been spread to many countries through the training programs. Almost all of the milling and baking laboratories in Latin America, for example, have some CIMMYT-trained staff.

Laboratory and other methods for analyzing soils and plants have been developed at IITA, and knowledge of these has been imparted to researchers through annual training courses jointly organized by IITA and the University of Guelph, Canada. The methods have been compiled into manuals that are currently used in laboratories in 46 Sub-Saharan countries as well as in Brazil, Peru, Belize, Indonesia, Sri Lanka, Papua New Guinea, Thailand, Malaysia, India, Hawaii, and Canada. Similarly, method and instrumentation for the assessment of soil erosion and physical degradation of tropical soils

have been developed and are now being used in Brazil, Ghana, Nigeria, Peru, and Tanzania. IITA has also developed methods for screening herbicides that have been adopted in laboratories in 22 African countries.

10.7 Professional Interaction and Services from the Centers

In addition to the activities discussed above that improve the efficiency of particular research systems on occasion, the centers provide professional interactions and regular services that increase the productivity of national research systems. Some of these services involve communication links between researchers from different countries. Conferences sponsored by the centers on important topics are a means for researchers to keep current in their field, to gain recognition and prestige, and to exchange ideas with colleagues. The international germplasm networks provide national breeders with the best varieties from around the world. Center publications provide both a source of new information, methods and ideas, as well as a place for the "problem-oriented" research worker to publish and gain recognition --- as contrasted to publication in the more "learned" journals.

Networking arrangements associated with the centers have been mentioned at several places already. The most common forms are the genetic materials testing networks discussed in chapters 6 and 2. Any researcher in a network can suggest materials to be included. Researchers in the network participate to the extent that each individual feels is best.

FEATURE: PRECODEPA; A NATIONALLY-RUN REGIONAL COMMODITY NETWORK

Programa Regional Cooperative de Papa (PRECODEPA), was formed in 1978 and now includes all nine of the Spanish-speaking countries of the Central America-Caribbean region. What especially distinguishes PRECODEPA is its structure and function as a collaboration between equals, of which the international center is only one. It is a "mechanism rather than an institution", composed of national programs and CIP. It does not interpose another institutional layer.

National potato programs make some commitment of resources in order to belong to PRECODEPA. Each national program sends two representatives to the Permanent Regional Committee — the national coordinator of potato research and the country's director of agricultural research. The committee agrees on projects of regional interest and appoints a Coordinator and two other representatives who form the Executive Committee which is in charge of executing projects and arranging for their periodic external review. CIP provides specialist assistance and training upon request. A problem is considered to be of regional interest if at least two countries agree it is a factor limiting production or per capita consumption of potatoes. The regional committee assigns priorities to problems by consensus, divides research responsibilities among its members according to interest and comparative advantage, and decides on training and workshop needs and participants.

The members fund their own national staffs and projects. Under a five-year agreement, the Swiss Development Corporation funds the regional component

of the operating budget drawn up by the Committee: travel, training and some non-personnel "tooling up" costs. This funding has averaged around $250,000 a year.

Seven of the nine projects established in 1978 still continue, with several others since added. Projects originally executed in the respective leader countries have spread to others as local expertise has developed. For example, Honduras has become a partner with Guatemala in the development of rustic storage. Mexico and Costa Rica, originally responsible for seed production, have been joined by Cuba (a new member in 1983). Other projects and leaders include nematode control (Panama), late blight resistance (Mexico), tuber moth control (Guatemala and Costa Rica), development of potatoes for warm humid tropics (Cuba), and a regional socioeconomic project (Guatemala).

PRECODEPA was set up to build national research capabilities and to take advantage of the possibilities of regional specialization and horizontal transfer, by encouraging national initiatives in setting programs and priorities, and working with international researchers. This offsets any tendency to create a permanent dependence on the international centers and the resentment against paternalism that it may engender, and helps to overcome bottlenecks in moving new technology into production.

According to Manuel Villareal, Coordinator of Mexico's National Potato Program and past PRECODEPA Coordinator, "the basic philosophy underlying PRECODEPA is that countries with strong resource limitations and similar agroecological, socioeconomic, and cultural conditions can advantageously divide among themselves the task of developing technical solutions of

productivity bottlenecks in food crops, and share research results." (ISNAR 1981). The Central America-Caribbean region largely fulfils these conditions with respect to potato production, a minor crop in this area. Such specialization and horizontal transfer can also use international center resources to better advantage, since the center only needs to interact with the regional specialist(s) for a given problem rather than at lower levels with each relevant national program.

PRECODEPA has promoted both national institution building and regional specialization and exchange. There have been sharp increases, some would say excessively so, in potato research and extension staff in member countries, entirely financed from national budgets, and the greater stability of personnel in the potato program than in beans and maize programs, the two principal food crops of the region.

There are a number of other networks focused on specific research problems (Table 10.4). Examples include the regional research networks for potatoes that are functioning in the Andean countries, in Central Africa, in Central America and the Caribbean (see Feature on PRECODEPA) and in South Asia, in which CIP has been instrumental. A network on soil fertility and fertilizer evaluation on rice is coordinated by IRRI, as is the Asian Farming Systems Network. IBPGR coordinates an extensive network of genetic collection work by joint program planning and a common research core.

Typically, participants in these networks meet once or twice a year to discuss results and modify ongoing work. Leadership rotates among the participants, sometimes being provided by an elected steering committee. A center frequently provides funds for network activities and sometimes also for research but, more often, the main research funds come from national sources or donors. Other centers achieve somewhat similar effects through regional programs. For example, CIMMYT has six regional maize programs, five regional wheat programs, and three additional regional programs in economics. These undertake many of the same activities as those of networks elsewhere.

One advantage of a research network compared to individual research activities is that experiences at various locations can partially substitute for variation over time at a single location and thereby speed the research process. This is effective when the experiences in similar locations within the networks are comparable. It is a particular advantage of small regional networks or even smaller collaborative projects. One year's work in three to five similar locations may possibly substitute for three to five years work in one location, at least for reactions to weather and other factors that vary over time.

Table 10.4 Some international agricultural research networks with center participation

Network	Center participant/ coordinator	Region	Countries	Year started
Proyecto Adino Cooperativeo de Investigacion en Papa	CIP	Andean	5	1982
Programme Regional d'Amelioration de la Culture de la Pomme de Terre en Centrale Afrique	CIP	Central Africa	3	1983
Programa Regional Cooperative de Papa	CIP	Central America and Caribbean	8	1978
South Asia Program for Potato Research and Development	CIP	South Asia	5	1982
Programa Cooperativade Investigacion en Papa	CIP	Latin America	4	
Asian Farming Systems Networks	IRRI	Asia	15	1974
International Network on Soil Fertility and Fertilizer Evaluation on Rice	IRRI	Asia, Africa	19	1976
[illegible]	[illegible]	[illegible]	18	1980

There are other services that national systems can use on request. The centers provide germplasm upon request to researchers who have a specific problem they are trying to solve. IRRI is working in shuttle breeding programs with the Chinese and Korean national programs and several others to provide faster multiplication of new materials. IRRI also uses its facilities to advance and rapidly multiply photoperiod-sensitive lines for national programs upon request. These collaborative endeavors speed up the selection process, and also subject lines to certain types of stress that are not otherwise as easily and quickly handled.

10.8 Some Pros and Cons of the Centers in Fostering Capacity

The impact of the centers on national research capacity could be judged against the hypothetical situation that would have obtained if there were no international centers. The main impacts of the centers on national agricultural research systems appear, from general observation to be: encouragement of investment in research, shifting research priorities toward food commodities and increasing research output through better organization, improved management, improved research techniques, the provision of germplasm, improving international scientific communication through data base services, international meetings, and publications. The possible negative effects include: diversion of national funds away from research, i.e., a substitution of center for national research (not supported by the analysis described in section 10.9), capture by the centers of funds that would otherwise have gone to national programs, and "pirating" of some of the best national scientists.

The intensity of center involvement varies considerably across countries. In a number of cases researchers or liaison scientists from the centers work in a research program over a period of time (Table 2.2). In such cases, the national program receives a full line of services - personal contact, joint research, training, communication with other scientists at conferences, etc. In most countries, however, none from the centers is stationed in the national system full time, although there are frequent visits by staff (Table 10.5). At the other extreme, some national systems are almost entirely isolated from the system.

There are some alternatives to the centers. In the past the Rockefeller and Ford Foundations epitomized good and successful bilateral programs in providing experts to national programs, but have largely ceased this practice since the establishment of the centers. Bilateral programs of the World Bank with a research emphasis also have offered an effective alternative mode of operation for some countries at different times. What was the International Agricultural Development Service (IADS) now a part of Winrock International, a creation of the Rockefeller Foundation, was organized specifically to assist national research institutions. There are numerous other consulting firms and non-government organizations able to provide advice on managerial and programmatic aspects of research. The FAO also works in this area. Nations face decision problems in selecting from among the various types of assistance offered by these diverse organizations including the international centers.

The primary alternative sources of new research methods for tropical research are the stronger developing country research programs and industrial country research institutions financed by foreign aid agencies. The centers offer services that seem to be efficiently competitive with these

Table 10.5 Visits by staff of some centers to national programs, 1983

Center	Number of visits by center staff members to researchers and national programs			
	Africa	Latin America	Asia	North Africa Middle East
CIAT	19	148	13	5
CIMMYT	145	291	122	59
CIP	16	99	48	16
IBPGR	24	19	16	5
IFPRI	16	11	31	8
IITA	310	65	24	8
ILCA	121	1	12	14
ILRAD	24	0	2	0
ISNAR	37	8	15	4
IRRI	4	7	262	19

alternatives. In the absence of the centers, it is plausible that fewer techniques would have been developed and, in the absence of the center networks, that these techniques would have spread less rapidly. Cuba provides an illuminating example. It has extensive ties with and is receiving equipment, funds and training from many countries in E. and W. Europe. However, Cuban researchers interviewed in the case study were emphatic that the tropical agricultural focus of the centers was central to domestic research advancement in Cuba. The centers are perceived to provide relevant technological components and research techniques not available to them from elsewhere.

There have always been communications between researchers, and there are many networks outside the CGIAR system. Researchers communicate through professional organizations that hold meetings and publish journals. National research institutions such as the USDA and the tropical agricultural research organizations of former colonial powers support formal and informal networks. They also store and distribute germplasm - some of it through regular varietal testing programs. Bilateral and multilateral aid donors also have provided at times, or continue to provide, communication through conferences and publications, and germplasm. But each of these alternatives is partial and intermittent, in part because the centers now exist and have been welcomed in taking over some of the coordinating roles once executed by others.

There are distinct advantages of the international centers over most of these other organizations. First, relative to international professional organizations, the centers have a larger set of researchers focused on the problems of tropical agricultural production and the type of research they encourage is generally oriented toward the practical problems of farmers.

Second, relative to support from national organizations, center-provided funding and participation is less influenced by political considerations. Third, relative to the networks sponsored by aid donors, there is more stability of activities over time. Bilateral aid in particular can shift quickly with changing political winds. The international center concept provides some protection against such shifts.

10.9 The Influence of the Centers on National Spending on Research and Extension and on Productivity

As described in chapter 3, national expenditures on research and extension rose impressively between 1959 and 1980. In real terms and in terms of the number of scientists, expenditure grew in all regions. Research "intensities", defined as the percentage of the value of production spent on research, also rose, typically doubling between 1959 and 1980. It was precisely during this period that research spending by the international centers was initiated and expanded strongly. This growth has engendered a debate about the influence of the spending by the centers on investment by national programs.

Some observers have inferred from the contemporaneous rise in both, that the centers have induced more national spending. Others have argued that, as with any form of aid, center spending tends to displace national effort, whose growth would have been even more marked were it not for the presence and growth of the centers. Support for this view point is drawn from the history of particular national commodity programs in countries hosting an international center. Still others argue that, while all centers may not have

displaced national efforts, their funding by the donors came at the cost of reduced effort in bilateral and other forms of multilateral assistance. As a consequence, no net addition to research effort has been made. In short, the range of opinion that abounds spans virtually every possibility.

These issues are both important and complex. Their importance for providing a clearer understanding of the global role and implications of the centers needs no amplification. The fact that different observers can use the same facts to reach opposing conclusions suggests that a number of underlying forces are at work; and only by endeavouring to capture their influence can the true relationships be untangled. An attempt was made with the study to do this but neither the data nor the theoretical constructs are completely adequate for the task. The findings that are overviewed here must, therefore, be regarded as preliminary and further investigation is surely warranted.

In order adequately to address the influence of the centers, it is necessary to disaggregate all research expenditure data by commodity. Interest focuses as much on the center's influence on spending on specific commodity research programs by national agencies as it does on overall research spending. This is because the centers' research, while covering all major food crops, by no means covers all the agricultural research interests of national programs. However, very few countries can provide a breakdown of research expenditures by commodity, and certainly fewer could offer this on an annual basis. Even where it is attempted, arbitrary allocations to individual crops of expenditures on such areas as soils, irrigation, pastures and fertilizer must be made. In this analysis (reported separately in a Study Paper by Evenson 1985), estimates of national expenditure on a particular commodity were made by allocating the reported total agricultural research

budget on the basis of data about publications obtained from the Commonwealth Agricultural Bureau and an adjustment for expenditure per publication using weights derived from a Brazilian study and applied to the other 24 countries in the sample. To the extent that relative costs of research on various commodities differ or countries vary their share of research in a particular commodity over time, the constructed series will be in error. Furthermore, if spending by the centers induces changes in the share as well as the total level of research, the results will fail to capture this.

Data for commodity research expenditures by country generated in this manner are summarized by region in Table 10.6. The research expenditures are expressed as a share of the value of output. Four points emerge from this table: (a) The research intensities across commodities are very uneven, (b) the research intensities for a commodity vary widely across regions; for example, rice research in Latin America is twice the level of rice research in Asia, (c) in almost every commodity, the research intensity in Africa is higher than other regions, (d) the share of the centers in total research funding varies widely. Globally, the centers' research represented 15 and 21 percent of cassava and potato research, but only 4 percent of rice research. This suggests that either the centers are over investing in roots and tubers relative to cereal research or that national programs are underfunding roots and tubers and the centers are compensating partially for this, or that the marginal return on center research in roots and tubers is significantly higher than in cereals. Only by formulating and testing such hypotheses will a clearer understanding of the centers' role emerge.

It is not possible to include all countries in this analysis as data for many of the variables used were not available, and so only 25 countries are

Table 10.6 Research spending by national and international programs: Average 1972-79 for 25 developing countries (percent)

Commodity	National research expenditures as a share of value of output			Spending by centers as a share of total research expenditures
	Africa[a]	Asia[b]	Latin[c]	
Wheat	1.30	0.32	1.04	4
Rice	1.05	0.21	0.41	7
Maize	0.44	0.21	0.18	11
Cassava	0.09	0.06	0.19	15
Beans	1.65	0.08	0.60	11
Pototoes	0.21	0.19	0.43	21
Groundnuts	0.57	0.12	0.60	2
Beef	1.82	0.65	0.67	2

a Ghana, Kenya, Nigeria, Sudan, Tanzania, Tunisia, Uganda, Egypt.

b Sri Lanka, India, Taiwan, Pakistan, Indonesia, Thailand, Philippines Korea, Malaysia, Turkey

c Argentina, Brazil, Chile, Colombia, Mexico, Peru, Venezuela

included; eight in Africa, ten in Asia and seven in Latin America. Together, these 25 countries produce over 90 percent of the total value of agricultural production in the developing countries excluding China.

For the analysis of the influence of the centers on national spending, two sets of data were constructed. The first involves observations for two periods, 1972-75 and 1976-80, for the 25 countries. For this set, data on various measures of foreign assistance were available enabling the influence of foreign aid on domestic spending to be considered. The second set has annual observations from 1962 to 1982 but includes only a limited number of variables. In both sets, observations are for a country, a commodity and a year. Twelve commodities were analyzed; ten from the centers' portfolios (rice, wheat, maize, sorghum, millet, cassava, beans, potatoes, sweet potatoes and groundnuts), together with soybeans and sugar. The approach taken was to specify a set of variables that were expected to explain the level of funding of national research and extension programs. A statistical analysis was then undertaken to determine the importance of each of these variables, after allowing for the influence of the others. National research expenditures by commodity, and total extension expenditures were specified in millions of constant 1980 US dollars for each country. The explanatory variables fell in three categories: economic, international and political. The economic variables featured were: the value of commodity production, an index of diversity among cropping patterns across geo-climatic regions, the relative costs of research and extension, and an index of land scarcity. The international variables intended to capture the influence of centers and others included: the cumulative spending by the centers on a commodity including an interaction effect with the total area in crops to allow for the likely complicating influence size of the country, the research investment by

neighbours in similar geo-climatic regions and a variable denoting whether or not a country is host to a center. The political variables employed captured aspects of: the extent of international trade, an index of farmers' terms of trade, the agricultural labor force as proportion of the economically active population in agriculture, an index of urbanization of the population, and an index of political violence. Allowance was made for the fact that the amount of foreign aid is itself influenced by the level of domestic research spending as well as being a determinant of that spending.

Detailed interpretation of the econometric results is available in the separate report by Evenson and also in Evenson, Pray and Scobie (1985). Only an overview of the empirical estimates is offered here. The overall effects of centers' induced investment are strongly complementary. Apparently in part in response to centers' cumulative investment in research on a commodity, national programs also invest in it — generally in a manner that rapidly (in from one to five years) matches the total amount invested by the CGIAR. The analogously associated changes in national expenditure on extension are usually an order of magnitude smaller.

The influence of the centers on domestic spending on both research and extension was found to be strongly related to the size of the country. Larger countries can benefit more from any given unit of research output from the centers simply because of their greater area of crop production. Hence, in absolute terms, they are encouraged to expand their own research funding by much more significant amounts following an increase in center funding. Not only do larger countries increase their spending by greater absolute amounts but their research expenditures per unit of crop area also rise. Larger countries apparently find it more worthwhile to expand research intensity than do small countries. Very small countries may reduce their research efforts in

the face of increased spending by the centers, drawing more heavily on support from the centers.

In contrast to the marked rise in national funding from an increase in center expenditures, there seemed very little net increase in research expenditures following a rise in general aid for research. For World Bank assistance to research there may be an even more severe displacement effect although a Bank loan for extension has a significant stimulus effect on national extension spending.

The overview thus far refers to non-host countries. For host countries there was no clear-cut relation between center and national spending. There was some suggestion that the effect has been positive but there is a difficulty in implying any causality. It may be that the centers have been located in host countries with a greater proclivity for expanding their agricultural research spending. When neighbouring geo-climatic regions increase their research effort, a country is typically induced to raise its own research efforts to internalize the benefits stemming from the greater regional research output. Similarly, where exports of a commodity become more important, research and extension effort is increased, and, in particular, greater output induces more research spending. Typically, a 10 percent rise in the value of output is accompanied by a 6 percent increase in research and extension spending.

On a commodity by commodity basis, spending by the centers was found to have a significant effect on national program spending on all the cereals except millet. While the effect on other staples as a whole was significant, individually, only in the case of potatoes was there evidence that spending by

national programs is related to the expenditure of the centers. Additional cumulative spending by the centers was found to have induced more than proportional spending on cereal research by national programs. For both cereals and staples, strong complementarity with rather than displacement of national effort was suggested by the econometric results.

An annual data set on commodity research in the same 25 countries for the years 1962 to 1982 was used in a further analysis addressed to the effects of research spending on production. The value of output of particular commodities was related to: measures of national research and extension, international research spending, area of the crop harvested and measures of the use of irrigation and fertilizers.

It is highly improbable that the influence of centers would be the same in all 25 countries, as generally centers will produce technology more closely matched to the circumstances of their host countries than to dissimilar environments. This will affect the productivity of the center's contribution and its interaction with national research and extension programs. A variable was defined to capture the extent to which a country's production of a particular crop takes place in the same geo-climatic zone as each center's principal location.

For any given level of research funding, it is of interest to ask whether there are positive or negative interactions between national and center funding. They were indicated as being generally positive for beans and sorghum but negative for wheat, cassava and potatoes. In similar geo-climatic regions, the effect was positive only for wheat. In similar regions the centers' technologies should more nearly match the requirements of the

national programs, so that center funding may not interact significantly with national funding to raise crop productivity. In short, the interaction effects measured between center research and national research and national extension spending provided general support for the notion that there is a substitutive rather than complementary effect between national and center efforts in similar zones.

Clearly, the productivity of national research and extension efforts varies tremendously across countries depending on organization and leadership, and the economic and political setting. The results pooled across the 25 countries must thus be regarded cautiously. Of major significance in the present context is the contribution of the centers.

It is instructive to overview first the results for the two broad groups: cereals and staples. In both cases, national and center spending raises observed productivity, the latter the more so in regions of greater geo-climatic similarity. Total center spending as a proportion of the value of output is quite low so that a small rise in cereal productivity over the entire cereal areas of 25 major countries implies a very substantial impact. Furthermore, the value of increased output far exceeds the research and presumably also other associated costs. For example the value of a 0.3 percent rise in cereal output might be, say, $130m a year globally while a 10 percent rise in spending on cereal research by the centers would represent an annual cost of only $7m and an implied marginal internal rate of return of the order of 100 percent. A rate so high follows from the fact that the contribution of the centers occurs not just in one country but over entire regions. Results for individual cereals were, however, found to be rather erratic. In the staple crops within similar regions, there were found

significant impacts of center spending on cassava, beans and potatoes. Cassava research has not seemingly raised productivity outside its own regions, however.

In summary, the evidence shows that spending by the national programs is positively related to spending by international centers. The centers' products include germplasm, research methods, information and training. These form intermediate inputs in the production of adapted technology by national systems. The productivity of their own investment is enhanced by the presence of these inputs. The effect is greater in countries with a larger cropped area because a unit of research effort generates results that can be more widely applied. In small countries, there is much less additional spending in response to the centers. This suggests that the centers should continue to foster mechanisms which raise the productivity of research in small countries and so encourage them to increase their research efforts.

The influence of spending on particular commodities presents a varied picture. In general, the spending on cereal research has engendered a greater corresponding response by national programs than has research on staples, although potatoes are a notable exception. It seems that research on staples has still to build up the accumulated stocks of knowledge that have come from the longer and more intensive history of cereal research. This result reflects the long lags inherent in crop improvement research, especially on an international scale. However, there are features of both the supply and demand for staples which have implications for the level of national research funding. They are often produced under small-scale, partly subsistence conditions in more remote rural areas; the ability of these producers to influence the allocation of resources at the national level is frequently very

limited. Furthermore, the demand for staples does not rise with increased incomes to nearly the same extent as does the demand for cereals. The share of the budget spend on staples falls sharply as income rises. In contrast, the demand for cereals for both direct and, even more crucially, for animal consumption is rising rapidly in developing countries. This, combined with their greater importance in trade, leads to higher research expenditures than for staples in most regions.

In contrast, the effect on productivity of centers' spending on staples in developing countries has seemingly exceeded that of cereal research. This may reflect the opportunities that have existed to make initial gains in previously neglected crops. In both cereals and staples, the centers' contribution to improved productivity is greater in geo-climatic zones similar to their own. The generally high rates of return associated with the research investment by the centers should signal the need for sustained spending on research.

Finally, it has to be stressed again that investment in research and extension, and the growth of agricultural productivity, are governed by the complex interplay of economic and political forces which occur in a wide variety of social and cultural settings. Understanding of these forces is less than complete and the data are less than ideal in their coverage, detail and quality. For these reasons, it would be premature to accept as definitive these overviewed findings. They do, however, represent a first attempt to estimate the effect of the centers on both funding and productivity while allowing for the impact of several of the other economic and political forces that might reasonably be expected to influence these two key dimensions.

10.10 Coda

* The growth of national agricultural research systems and international research centers are mutually reinforcing processes. International centers cannot have much impact on farming unless there are researchers to do adaptive work at the national level and extension workers to help to take ideas to farmers.

* The aggregate growth of national research systems over the past quarter century has been rapid but some important activities cannot readily be carried out by some national institutions and many national programs still have important weaknesses. The international centers continue to have an important role here.

* One of ILCA's more important products to date has been the analytical services that it provides to national agencies which have large data bases on animal production. Researchers analyze the data at ILCA with the assistance of ILCA staff. The results have also been used to assist in the preparation of livestock development projects.

* On-farm research programs have been promoted by the centers and are being used by national researchers as an input into the research planning process.

* CIMMYT's station managers have worked with people responsible for

experiment station management in more than 25 national programs. Some of the techniques evolved are now being applied in Ecuador, Tanzania, Pakistan, Turkey, Thailand and the Philippines.

* One of the most important new research approaches which centers have developed and popularized is the procedure of making a large number of crosses and exposing them to heavy pressure from relevant pests and diseases. Techniques for the mass production of downy mildew inoculum were developed by the Philippine and Thai national programs with CIMMYT collaboration. CIMMYT methods for testing the milling and baking qualities of wheat have been spread to many countries through the training programs.

* The centers provide professional interactions and regular services that increase the productivity of national research systems. They play an important role of linking national agricultural research systems together through research networks which may take a wide range of forms. Some are networks focused on specific research problems. IBPGR coordinates an extensive network of genetic collection work. One advantage of a research network compared to individual research activities is that experiences at various locations can partially substitute for variation over time at a single location. Collaborative programs speed up the selection process, and subject lines to certain types of stress that are not as easily and quickly handled otherwise.

* International research centers can influence national research capacity (a) by indicating the importance of research, (b) through projects to build national institutions, and (c) through the regular services they provide to the national systems.

* The existence of the CGIAR has considerably affected the level of finance available for national agricultural research. Collaboration with the centers raised the productivity of research and helped to convince governments that there are high returns to research.

* The Rockefeller and Ford Foundations have long been concerned with world food problems, and they took strong leads in supporting agricultural research addressed to their solution. Asian food production has clearly justified that support. There is less evidence of research benefit in Africa, where the investments were made later and the base of commodity-specific knowledge was generally lower.

* The inducement effect on research priorities is clearest where counterpart commodity research programs did not exist prior to center involvement. For example, only India had a national cassava research program before CIAT was established. Collaboration has led to increases in the size of existing programs in many countries. National research investments increased more rapidly for commodities being researched by the CGIAR centers. For example, Syria's research on field crops corresponding to ICARDA's activities made up about 42 percent of the projects in 1978, while by 1984 it made up 73 percent.

* Some cases are cited as examples of centers "crowding out" local research, especially in countries that host centers. IRRI research appears to have been a partial substitute for national rice research in the Philippines, for example.

* Some of the specific commodity programs instituted with center stimulation have attracted comment because they absorb significant research resources on commodities which make up a small share of the value of output (e.g. potatoes in the PRECODEPA countries).

* CIMMYT's emphasis on breeding maize composites rather than hybrids has had a significant impact on many maize research programs in Latin America and Asia.

* Perhaps the most important impact of the centers on research priorities has been the orientation of researchers toward solving farmers' problems. Researchers in the centers provide prestigious role models for national research workers. Training programs at the centers also stress applied research in farmers' fields. The Nile Valley project of Egypt and Sudan in which ICARDA is centrally involved is a good example of encouraging national scientists to work on farmers' problems in farmers' fields. The centers have actively encouraged use of interdisciplinary teams.

* Some national institutions have used the structure of centers in designing their own activities. For example, EMBRAPA in Brazil established a series of commodity institutes organized in multidisciplinary teams as the basic structure for its new national agricultural research system.

* ISNAR assists countries in the identification of desirable organizational changes and needed support. It has recommended institutional and organizational change in 12 out of the 18 countries where its major review and planning missions have been completed. More than 130 individuals, most

from Africa, have participated in ISNAR's research management training programs.

* IBPGR has been responsible for some important new institutions - the development of new national genetic conservation programs in about 50 countries and the development of national genetic resources committees in 25 countries.

* The main positive impacts of the centers on national agricultural research systems appear to be: encouragement of investment in research, shifting research priorities toward food commodities, and increasing research output through better organization, improved management, improved research techniques, the provision of germplasm, improving international scientific communication through data base services, international meetings, and publications. The possible negative effects include: some diversion of national funds away from research covered by centers, capture by centers of funds that may otherwise have gone to national programs, and loss of key national staff to the centers.

* In the absence of the centers, it seems likely that there would have been fewer improved farming techniques developed and, in the absence of the center network, these techniques would have spread less rapidly.

* Spending on research by the international centers may influence the level of spending by national programs. The centers provide genetic materials, research methods, training and information. These represent intermediate inputs into the production of new knowledge and technologies by national programs.

* Where these products of the centers are closely tailored to match the ecological circumstances of the collaborating countries, the presence and spending of the centers may displace national research efforts. On the other hand, the provision of these products by the centers could be expected to provide both greater opportunity and capacity for national programs to test, adapt, modify and disseminate technologies relevant to local conditions.

* An analysis of the factors determining national spending on research and extension was undertaken. A wide range of economic, international and political variables which might be expected to influence national spending was included in order to isolate the effect to the centers' activities. Data for 12 commodities in 25 countries were used.

* An increase in the total spending by the centers on field crop research was found to be associated with increased spending on both research and extension by national programs. Investment in research by the centers appears to have a greater enhancing effect on national spending than other forms of aid.

* The amount by which national spending rises in response to increased effort by the centers is strongly influenced by the size of the country. Countries with large areas of crops can capture more benefits from the products of the centers simply because there is a greater scale of production to which to apply new technologies. They increase their funding both absolutely and relatively more than small countries. The risk of displacing national efforts is much greater in small countries.

* Increased research effort by neighbours in smaller geo-climatic zones

also seemingly induces greater national research spending as countries have expanded possibilities to capture relevant technologies.

* Research spending by both national and international agencies raises agricultural productivity. In general, a 10 percent rise in the expenditure by nations and centers on a particular commodity subsequently raises national productivity by about 1.1 and 0.3 percent, respectively. Because the results of center research are applicable to wide regions, the implied marginal rates of return are very high - of the order of 100 percent.

11 AGRICULTURAL AND FOOD POLICIES

Why have prices fluctuated? Why does the distribution of gains from new technology differ so markedly?

Relaxing the biological constraints to production has been an important force in the world food economy. It must continue to be so, demanding the sustained efforts of both the national and international components of the global research system. However, to understand (and influence) the consumption of food, both in its level and reliability, requires attention to the economic, political and institutional environment. Here, the issues transcend those of technological change, per se. Production, consumption, distribution, foreign trade and prices of food reflect economic, political and institutional factors as well as the technological circumstances.

It has become increasingly evident that the supply of relevant technology for food production is a reflection of conscious decisions made about the level and nature of investment in research. In an analogous manner, the economic and institutional setting is itself a reflection of deliberately chosen policies. Furthermore, the development of richer theories, together with a greater body of evidence has highlighted the fact that it is not only those policies directly related to or arising from the agricultural and food sector that are of importance. A broad range of economic policies, be they monetary, fiscal, trade or international policies, influence the production, distribution, consumption and pricing of food. These policies have a direct and important bearing on: (a) the supply of technological change; (b) the demand for technological change; and (c) the impact of technological change. Research which leads to an improved understanding of the nature and role of policies, and helps to alleviate the constraints they impose, is an important element of global agricultural research.

11.1.2 Diversity of issues

Agricultural and food policy embodies the collective efforts of national and international agencies to influence the environment of producers, consumers and traders. Such intervention is directed at achieving such social goals as improved nutrition, higher rural incomes and employment, greater self-sufficiency, and improved food security. Research on food policy involves (a) the development of analytical schemes which, when bolstered with empirical evidence, reveal the complementarities and conflicts between the various objectives; (b) identifying the instruments through which both national and international intervention policies can be implemented; and (c) quantifying the effect of changes in policy on social objectives.

In order to undertake such research effectively, food policy analysts must concern themselves with issues ranging from food production, the generation and diffusion of new technology, the enhancement of the physical and human stocks of capital, the distribution and pricing of food, and the roles of trade and international policies. In every case, there is a multitude of policy alternatives which directly and indirectly affect such outcomes. The wide scope of the issues and the range of potential instruments make the resulting analyses complex. There are no easy alternatives. Some indication of the scope of food policy questions can be gauged from the following example.

In many developing countries, overvalued exchange rates have been a characteristic of attempts to accelerate economic development through industrialization. The results have been to lower the price of tradeable relative to non-tradeable goods. Imports are made cheaper (although their quantities

are often restricted), and exporting becomes less attractive. The implications for the production, consumption, and trade of foodstuffs of this economic development strategy, seemingly unrelated to agriculture, are manifold.

The strategy will tend to hold down the local price of tradeable foodstuffs, providing protection for low-income consumers. But depressed prices will discourage domestic production and result in less incentive to invest in agriculture, be it in research, education, extension or physical capital. Such investment will appear less attractive when agricultural output is undervalued. Resource allocation between the sectors will respond accordingly.

At the same time, output, employment and income growth in agriculture will be held back. This will encourage migration out of agriculture - a tendency further enhanced by the attraction of higher urban wages, a result of labor unions capturing part of the rents generated by industrial protection.

With a rising urban population and declining, or at best stagnant, food production, pressure will be placed on the government to import food to hold down prices and wage costs. Continued poverty will result in pressure for food subsidies for some, or even all, of the population, certainly in urban areas. The combined effect of increased food imports and subsidies on consumption will be to place additional pressure on both the internal and external accounts of the country. Balance of payment difficulties will be worsened by a decline in agricultural exports.

To hold down the budgetary costs, the government may instigate forced deliveries of food by local producers, ironically at prices significantly below those which it pays foreign producers for imported supplies. When foreign exchange crises arise there will be little scope to cut food imports made "essential" by the other strategies being pursued. Imports of capital goods can be curtailed, reducing the growth of the capital stock; and imports of raw materials will be retained, reducing the utilization rate of the installed industrial capacity. Employment and output in the industrial sector will tend to be destabilized.

This simple example serves to illustrate the breadth and complexity of the issues in food policy analysis. In countries where agriculture is an important sector, the connection with the rest of the economy will be significant and complex. Food policy research faces a dauntingly diverse menu of important issues.

11.1.3 Design of technology

Of particular importance to the work of the CGIAR is the role of policy research in the design, generation and diffusion of new agricultural technology. A significant contribution of such work may be to assist biological research workers to justify their work, and to orient their work to achieving a broad spectrum of social goals. Some examples will serve to illustrate this role of policy research.

In an attempt to raise nutrient intakes, plant breeding programs are sometimes directed toward enhancing the nutrient quality of a crop. This may involve both a long and difficult task and some tradeoffs with gains in productivity. Higher protein content in rice, for example, generally only

comes at the cost of lower yields. Could an equal gain in nutrient intakes be achieved by altering the mix of crops? What is the gain if increased output alone is the target? How will the production of other crops be affected? What are the effects on employment and incomes and hence on the demand for food? How are these changes distributed between the poorly and the adequately nourished? Are there other instruments (maternal and child care, health services or food subsidies) that might be used to address the nutritional needs of a specific group? How effective are these? Are they cost-efficient? Such are the questions to be addressed by the policy analyst.

Concern has been expressed about increased variability in the yields and output of food crops. A natural and immediate reaction is to focus on the genetic improvement and the associated agronomic practices. Can varieties be developed with greater ability to withstand disease, inadequate fertilizer or water, extremes of heat, etc. But the problem calls for a much more complete assessment of the causes and magnitudes of instability, combined with a broad perspective on the wide range of possible instruments. Would other changes in the farming system offer less costly ways to enhance stability? Could the mix of crops be altered? Would more ready access to fertilizer and pesticides reduce variability? Would investment in irrigation schemes lower the risks? Would crop insurance ameliorate the effects of instability? Would holding additional buffer stocks or greater reserves of foreign exchange be an effective means to lessen the variation in consumption? Would improved access to domestic water and fuel supplies release labor for crop protection tasks? Would concentration on achieving higher yield alone reduce the need to expand production to more marginal areas and so lessen the variability of output? An apparently straightforward technical matter is, in fact, amenable to a host of

potential approaches that may be made more explicit in effective policy analysis.

In a cassava growing area of Colombia, large-scale farmers achieved high yields from monoculture while, alongside, small-scale farmers used complex multicropping systems that yielded much less. An initial reaction of researchers was to emphasize the need for improved cassava varieties tailored specifically for multi-cropping systems of the small farms. It seemed that not only should yields be an objective of the breeding program, but plant architecture, timing of maximum foliage density, and length of growing cycle should all be reflected in the breeding strategy. It was argued that only by incorporating these criteria into the breeding strategy would technology be produced relevant to the circumstances of the small farms. On closer inspection, however, it was learned that these farmers used a multicropping system as it lowered the need for pesticides, although the total net returns were much lower than from intensive monoculture. Because of a subsidized credit scheme, there was excess demand for credit. This was handled by the use of non-price rationing methods which excluded the small-scale, politically powerless, illiterate farmers. Without credit they could not acquire the inputs needed to produce high-yielding crops of cassava for a profitable fresh market. In such circumstances, it is conceivable that an increase in the interest rate on agricultural working loans would raise the output and net incomes on small farms much sooner and much more substantially than breeding for a cassava type to suit a multicropping system. Only through the effective collaboration of breeders, agronomists, and economists would such issues be addressed.

Attempts are currently underway to remedy the poor performance of African agriculture. Appropriate steps will only follow correct diagnosis, which itself will require assessments of both the technical and policy environments. Has the slow growth and declining output per head been due to lack of relevant new technologies? Does much of Africa, in fact, face shortages of labor rather than of land? Has enough attention been given to the policy and practical implications of the facts (FAO 1984a,b) that women contribute an estimated two-thirds of all hours spent in traditional African agriculture, three-fifths of the hours spent in marketing and, in most areas are the primary producers of food for domestic consumption? Has the spread of new technology been impeded by policies that undervalue the output of agriculture? Have those discriminatory policies themselves altered the rate and direction at which new technology has been generated?

Since its inception, the CGIAR has been concerned to try to ensure that the main share of any benefits stemming from technological advances is captured by poor people. By quantifying the effect of a technological change on the demand for factors, labor income and consumption patterns can provide a better understanding of the links between technology and income distribution. In short, a concern for equity must involve research on both technological and policy issues.

12.2 Policy Research in the CGIAR System

12.2.1 History and objectives

From its inception, the Consultative Group was concerned with issues of food and agricultural policy, particularly insofar as these impinged on the generation and diffusion of technology for food production. A seminar on

socioeconomic research in the centers was convened in 1973, and the matter was subsequently taken up by the TAC. In July 1974, the Chairman of the TAC presented a recommendation to the CGIAR for the establishment of an international center to undertake studies in key policy issues relating to world agricultural development, particularly to food problems. At its meeting in October 1974 the TAC proposal had been further considered but had failed to receive a clear consensus of support. It was agreed that the CGIAR would take no further action at that time, although it was recognized that some individual donors may wish to; in that event, the CGIAR expressed interest in maintaining close links. Finally, after the results of the pending world food conference were known, and in view of the pioneering nature of such a venture, the Group agreed it would be prepared to reconsider the question of sponsorship at some time in the future.

IFPRI was formally incorporated in early 1975, receiving its funding from a group of three donor members of the CGIAR. In 1978, the sponsors sought to have the Institute's funding transferred to the CGIAR and, following a TAC recommendation, this was accomplished in 1979. The TAC recommended that IFPRI's mandate should give principal emphasis to problems in developing countries, and that it should focus on the linkages and interrelationships between the farm-level problems of the adoption of new technology, and wider socioeconomic aspects of agricultural development.

11.2.2 Current research on policy in the CGIAR system

Research related to food and agricultural policy is undertaken by (a) a majority of the individual centers, (b) IFPRI, and (c) TAC and the CGIAR Secretariat. Social scientists are on the staff of 11 of the 13 centers (ILRAD and IBPGR being the exceptions).

Policy research in the centers

There are basically three different types of organizational arrangements for research on policy matters at centers other than IFPRI. (While ISNAR's work does involve social science research and is related to policy, specifically to the funding and management of research, it is not included here; see chapter 10). The organizational approaches can be classified as Systems, Disciplinary or Commodity.

(a) Systems Approach: Social science work is included as part of a farming systems group. This model is used by ICARDA, IITA, ILCA, and IRRI, (the latter having a small portion of its economics resources in the Farming Systems Program).

(b) Disciplinary Approach: Social science work is conducted by a separate department of economic or socioeconomic research. This is the case in CIMMYT, CIP, IRRI, ICRISAT and WARDA. In addition, ILCA has a Livestock Policy Unit. Much of the work undertaken by the centers with disciplinary denominations is actually closely linked with farming systems research.

(c) Commodity Approach: In this model, adopted only by CIAT, all social science work is conducted as part of multidisciplinary teams each addressing research for a particular commodity (tropical pastures, beans and cassava).

The primary focus of social science research in these centers is the generation and diffusion of new technology. Understanding the technical and economic circumstances of producers, using that information to guide the development of new technology, estimating the payoff to alternative research

strategies, collaborating in trials on station and farms and documenting the adoption and consequences of new technology, are the activities which form the core of the social science research done by the centers.

Overall, aside from IFPRI, here has been little work directed specifically at food and agricultural policy per se. To engage in such work is generally seen as diverting resources from the immediate targets of biological research. It was felt for a long time that such matters were solely the domain of national governments and that, to be seen to be addressing domestic policy questions, would imply an intrusion into sovereign affairs which might jeopardize good working relationships with national programs and their political masters. An international center could legitimately collaborate with the scientists in a country and influence their aims and methods. This was seen (perhaps naively) as a politically neutral activity. To engage in direct contact with policy makers was seen as risking accusations of political meddling.

In practice, however, the individual centers have found themselves faced with a continuous need to assess the policy environment in a country, just as much as they must assess the agro-ecological circumstances. This has lead some of them to examine systematically the structure of incentives facing producers and consumers of the particular crop in question. The work on maize and wheat by CIMMYT in a number of countries is a notable example of this type of policy research. It does raise a difficult question for the centers: should they endeavor to improve crop technology in a setting which is agronomically favorable but where the structure of incentives is so unfavorable that any widespread adoption seems unlikely? Do they take the economic climates as given? There is no definitive answer to such a problem.

Economic climates can and do change and, by undertaking this type of research, a center is better able to know where its work may have impact and thus to, allocate its own resources efficiently, and at the same time to engage in discussions with national policy makers on the basis of concrete analyses.

A number of the centers (notably CIAT, CIMMYT, CIP, ILCA, and IRRI) produce periodic statements of statistical trends in output, prices, trade and consumption for the crops in their mandates. These are particularly useful. The recent issues from CIMMYT also contain carefully researched and documented essays which synthesize important global developments for the crops. There is a very wide potential audience for this material and it plays a useful role. The other centers might consider preparing such statements and giving them wider distribution. At present a number are produced and used only within - center.

As a result of continued close scientific collaboration, both economists and biologists at the centers have had informal contacts with those responsible for setting policies. Frequently, these contacts have arisen as a logical consequence of potential technological advances. The introduction and spread of a new variety may depend heavily on the supply of inputs, the delivery of water, the provision of transport and processing facilities, the prices paid to producers, or the availability of credit. By generating potentially significant advances, the technical possibilities facing a country are altered. This creates disequilibria, the very essence of technological change, and calls for a whole series of responses, many falling directly in the domain of public policy.

Through this indirect mechanism, the centers, while focusing primarily on the generation of new technology, are, in fact, legitimately involved in discussions on policy issues. In some cases, this has encouraged them to undertake some specific research activities related to policy matters, and to launch some new initiatives, such as the policy unit at ILCA.

This recently formed unit has three objectives: (a) to identify major policy questions relating to African livestock development; (b) to conduct research on selected issues; (c) to bring the results to the attention of those making policies for the sector. Current work includes a study of the size and composition of public expenditures for the livestock sector and the consequences for African consumption and production of increased imports of dairy products. The first major study completed was an analysis of the markedly different performance of the livestock sectors in various African countries from 1965 to 1980, explaining differences in the rates of growth of livestock production. Information about the relative importance of technical and policy constraints in different settings can be of value to both the center itself in setting its priorities for biological research, and to national policy makers.

Such undertakings by individual centers must inevitably stimulate debate about the role and scope of policy research in the CGIAR system as a whole and the best way to conduct the policy research that is found to be germane to the CGIAR mission. There will always be issues that are directly linked to particular technologies or regions and which consequently lend themselves to being addressed by the individual centers. It is arguable that the future impact of the centers may well be higher to the extent that both the scientific staff and the leadership are constantly informed of changes in

economic climates and global trends that affect the countries and crops in their mandates. The risk of such efforts is that they become piecemeal, sporadic attempts built on an inadequate base of analytical capacity and experience in policy issues. As some of the important issues are more global than local, a proliferation of policy research in the centers would inevitably suffer from some duplication. To ensure that the maximal contribution is obtained from resources devoted to policy research in the CGIAR system, continued scrutiny will be needed to determine the best allocation of efforts between IFPRI and the individual centers.

IFPRI

While less than one-third of the total social science staff of the CGIAR system is in IFPRI, its mandate is designed for it to undertake the majority of the research on policy matters. While the micro-economic focus of the work done at the centers has always been seen as valuable, the TAC felt that many policy issues arising from the work of the center economists, and macro-economic policy issues such as commodity trade and price policies, were neither adequately addressed nor appropriately undertaken by the existing centers. For this reason, the system was seen to have a weakness to be remedied by the inclusion of IFPRI.

IFPRI's work is organized in five research programs:

- Agricultural Growth Linkages and Development Policy
- Food Data Evaluation
- Food Production Policies
- International Food Trade and Food Security
- Food Consumption and Nutrition Policy

In 1982, a long-term plan was developed in which the work of each of these programs was integrated and focused on six principal questions:

1. What food policy adjustments are needed in response to rapid growth in food import demand by developing countries?
2. What policies will allow technological change to play its central role in raising food production in developing countries?
3. What combination of farm product incentives can achieve growth and equity simultaneously?
4. What relative weight should be given to alternative agricultural commodities in future production patterns?
5. What policies are needed for technological change in agriculture to stimulate the growth of income and employment necessary to alleviate rural poverty?
6. How can food security be provided to the world's poorest people in the face of unequal distribution of income, fluctuating production, and high costs of storage?

With the creation of IFPRI, the CGIAR system now has the capacity to review both the on-farm and intrahousehold constraints and the policy constraints to greater food production and improved welfare. There is a natural specialization which follows from the comparative advantage that the other centers have relative to IFPRI. Many of the on-farm issues are highly locational specific or relate to the regions for which the individual centers have their mandates.

One of the criteria for guiding the evolution of the CGIAR system has been to contribute to areas of research not adequately addressed by others. Research on basic foodstuffs had frequently been neglected in developing

countries, and the efforts of the CGIAR have always been seen as contributing to filling this gap. Given the critical role of the agricultural sector in economic development, there has probably been substantial underinvestment on research in agricultural and food policy in developing countries. In a manner analogous to the role of the centers in filling gaps in biological research, IFPRI has a role to compensate for some gaps in policy research. By concentrating a critical mass of skills and resources in a centralized agency, IFPRI is able to undertake this role in a presumably cost-effective manner.

The CGIAR Secretariat and the TAC

Finally, both the Secretariat and the TAC periodically sponsor studies related to the allocation of research effort, the establishment of priorities, and the evaluation of the impact of research. These have implications for policies within the CGIAR system, for other international agencies, and for national governments.

11.3 Contributions

11.3.1 Evaluation and attribution

In this section the realized contribution of research on policy within the CGIAR system is addressed. Such an exercise is beset with even greater difficulties than those confronting the evaluation of the impact of new biological technology. The spread of a new variety does provide some tangible evidence of technological advance, and at least some data on areas and yields are usually available or can be estimated. Identifying even the existence of a new policy can, in and of itself, be a difficult task; isolating what its impact may have been is fraught with pitfalls. Of particular importance is the question of attribution. Even to ask what the impact of policy research

by the CGIAR system has been is to raise questions about the legitimate role of the system in relation to sovereign states. Policy research can only have an impact if its findings lead (a) to changes implemented in actual policies, (b) to the avoidance of unwise policies or (c) confirmation that existing policies are best. But such results depend on decisions by national governments and to attribute any actual impact to the CGIAR could easily be construed as politically insensitive, and by some as evidence of meddling in national affairs. More particularly, it is seldom realistic to try to segregate the effects of particular pieces of policy advice or analysis from all the other inputs that go into policy formation. For these reasons, it is deemed appropriate to view the impact of research on policy as coming through the generation of new knowledge about alternative policies and their outcomes, and the contribution that such knowledge makes to informed debate surrounding policy decisions.

11.3.2 Policy studies

In this section, some selected examples are discussed to illustrate the role that policy research is playing, the nature of the links that have been forged, and the contribution of the new knowledge to policy making.

Contribution of biological research to policy making

As stressed in section 11.2.2, the principal role that the biological research centers have played in policy formulation has not come from direct involvement in policy research. Rather, in the process of developing new technologies for specific areas, both social and particularly biological scientists from the centers have engaged in continuous discussion and exchange of ideas with those responsible for policy formation. This is a natural product of the collaborative work of the centers with national scientific

programs. Both the need for and the effectiveness of such activities are greater when the adoption of relevant technologies is being impeded by constraints that would be amenable to release through modifications to policy. A strong collaborative scientific effort that is generating potentially significant advances will often form the basis for discussions, albeit of an informal nature. When the magnitude of potential gains in production or productivity is appreciated, and the distribution of the costs and benefits understood, policy makers become increasingly aware of the costs imposed by, say, inadequate access to inputs, lack of processing, or subsidized imports. For example, adoption of a new technology may be impeded by trying to force the use of certain inputs through restrictions tied to credit. Once the magnitude of the potential gains is established, the new technical possibilities can lead to a change in credit policy.

The existence of fertilizer-responsive varieties has increased the derived demand for fertilizers and led a number of Asian countries to allow greater imports and to foster domestic production in order to capture more fully the potential gains in output offered by the new technology.

The same argument applies to irrigation. The returns to investment in irrigation schemes are enhanced by the presence of high yielding rices and this change in the technical possibilities induces changes in the public irrigation policies. The existence of new pasture species which raise the productivity of marginal acid soils increases the returns to investment in roads and induces changes in the policies toward investment in infrastructure.

The presence of a new technology for processing cassava is leading to changes in Colombian public investment with the establishment of pilot

processing plants and plans for over 300 plants involving capital investment of US$3 million per year for five years.

The rate of these induced changes in policies may be accelerated by specific research studies undertaken at the centers, and by engaging in direct discussion, as in the case of the policy seminars conducted by CIMMYT. These were linked strongly to CIMMYT's work in generating new technology by being focused on what do policy makers need to know about farms and farmers in order to facilitate the development and use of improved technologies. Seminars organized on a regional basis were held in the Philippines, Colombia, Bangladesh and the Dominican Republic. The skills of outside specialists were enlisted, and case studies presented on public policies related to agriculture.

Evaluation of returns to research

Another channel through which the centers have had an indirect influence on policies is through studies that evaluate the return to research. These are of two types.

In the first type, estimates are made of the expected returns to research at a center that is either planned or underway, but has yet to have an impact on production. In the second, measurements are made of the economic returns to past investment in research and the distribution of any net benefits is examined.

The first type of study is aimed at improving the allocation of research resources within the centers themselves in order to increase the productivity of research, i.e., to ensure that the maximal amount of new and relevant

knowledge is generated by a given amount of research resources. To the extent that the centers are effective in doing this, there may be two indirect effects of relevance to the national programs. First, greater productivity from the resources available to the centers should allow wider and more effective collaboration with national programs and may help them by enhancing the productivity of national research programs which, in turn, allows them to capture funds more successfully from bilateral and other international agencies. The second indirect influence arises from the demonstration effect of the use of analytical methods for assessing the payoff to research. For example, the interest expressed by the director of the Mexican agricultural research system in drawing on work on research project appraisal done by CIMMYT is evidence of this type of effect on research policy.

Much of the work on the expected payoff to research is logically for use within the centers - it is their research policy rather than that of national programs which is the primary target. Both IRRI and ICRISAT have made major efforts in this field, IRRI examining the payoff to research across different rice cultures, and ICRISAT examining the congruence between its research effort and that suggested by a broad range of agronomic, social and economic indicators. This work covered all the crops and the regions in the ICRISAT mandate. In its long-range plan, CIAT examined the expected rate of return to investment in each of the major crop programs. However, in general, the centers do not appear to have devoted as much systematic and sustained effort to research assessment as seems warranted.

The second major type of assessment study concerns the payoff to past research, based on actual costs and realized gains. This is important work in which the centers have undoubtedly underinvested. Not only would their own

claim on resources be strengthened by more vigorous documentation of the magnitude and distribution of the benefits and costs, but the demonstration effect for national programs could be potentially significant. Low and variable levels of funding have characterized many national research systems. Careful studies showing the returns to collaborative efforts, whether they be in breeding (as is the case of rice in Latin America and Asia) or research methodology (as in the case of on-farm trial work by CIMMYT in Panama), can provide information that should be valuable for formulating research policy in national programs.

Nutrition policy

Biological research can affect the supply of nutrients by the selection of commodities for study, and by improving the nutritional quality of a given commodity. The powerful effect of research on basic food staples, the essence of the CGIAR approach, on the supply of nutrients has been well documented. Concerns that the improved cereal technology resulted in a reduced supply of proteins in India were largely allayed by the work at ICRISAT. The centers' varying positions on nutrition were recently brought together in an IFPRI-organized Inter-Center conference on Nutrition and Agricultural Research (Pinstrup-Anderson 1984).

Given the changing views of the role of protein in alleviating malnutrition, and due to the trade-off between yield and protein content, it is now the stated policy of the centers to give only secondary attention to protein content. Implicit in this position is the argument that the cost of achieving unit increases in the total supply of protein through research is lower by focusing on high yielding and widely adapted varieties than through breeding for higher protein content or quality. Again, the work of ICRISAT in

quantifying these issues has been valuable for guiding national research policy and avoiding an excessive diversion of resources to the improvement of protein content.

Notwithstanding the critical comments on this topic in chapter 8, it is notable that CIMMYT has had a substantial (now dimished) program of research on quality protein maize. It appears that this has been an outstanding technical achievement, as varieties with enhanced nutritional value and equivalent yielding levels have been developed, and are currently released in Guatemala. This has been a difficult project, however, absorbing significant funds. Given the experience and analyses of other centers, it is not evident that the contribution to total nutrient supply (or intake by protein-deficient groups) is higher than it would have been had those funds been dedicated to yield-increasing technologies. Expenditures on nutrition-related research of this magnitude demand scrutiny of their expected contribution to nutritional goals relative to alternative uses of the funds. In this particular case, the CIMMYT strategy influenced the allocation of effort by the Guatemalan national program. Resources devoted to the testing and promotion of quality protein maize had alternative uses which conceivably, with the wisdom of hindsight, could have had an even greater contribution to nutrient supply. On the other hand, several countries that had initiated research on soft endosperm opaque 2 maize following the pioneering work at Purdue University reduced their activties and relied instead on CIMMYT-developed germplasm.

Input policies

Research done by IFPRI on irrigation in S.E. Asia stimulated considerable discussion in the Asian Development Bank and the Philippine National Irrigation Administration. Estimates of long-range investment

requirements are being used in planning by these institutions. The results of the study have influenced irrigation investment policy toward small-scale diversion schemes rather than the traditional large-scale reservoirs.

Also in the Philippines, research results from IFPRI about the impact of rural credit markets on farm output and incomes have been used in revising interest rate policy.

IFPRI's collaboration with Mexican analysts contributed to changes in the design of the crop insurance program for rainfed areas. A broader collaborative effort with the Interamerican Institute for Cooperation on Agriculture resulted in a conference on crop insurance involving analysts and policy makers from many countries. By the careful documentation of the theory and administration of crop insurance and of experience with schemes in a variety of settings, the conference papers alerted policy makers to many of the pitfalls, and have encouraged a number of countries to undertake careful evaluations before embarking on large and costly insurance schemes.

Research on mechanization done jointly by A/D/C and ICRISAT provided information for Indian policy makers in their decision on import policies for agricultural machinery.

Initial research by IFPRI on the costing and sequencing of investments in rural infrastructure has been completed, and the results incorporated in long-range planning by the state government in Andhra Pradesh.

Through collaborative work with the Bangladesh Institute of Development Studies, IFPRI has examined the role of food-for-work schemes as a mechanism

for developing rural infrastructure. This has led to a number of changes in the management of the schemes and a heightened awareness of the opportunities for using food aid to achieve a productive impact.

IFPRI's direct collaboration in Bangladesh has provided information for the government to restructure its fertilizer policies, devising strategies that could sustain an increasing trend in fertilizer consumption without the fiscal burden of subsidies.

Food subsidies

Subsidies aimed at lowering consumer prices are prevalent in developing countries. Both their fiscal and economic costs are often high. Research can contribute to better understanding of how to improve their cost effectiveness in addressing the needs of the poor while minimizing the fiscal costs, negative effects on growth, and disincentives to domestic food production. IFPRI has made a substantial investment in research on food subsidies with detailed studies in 12 countries. The largest single country study has been a collaborative project in Egypt. This work featured:

(a) collaboration with a national institute;
(b) close ties developed with policy makers at the ministerial level from the outset;
(c) IFPRI staff based in the country to maintain close contact and provide overall project supervision;
(d) a major collection of primary data from households covering food purchasing and consumption patterns in both rural and urban Egypt;
(e) a broad mandate that has covered the impact of subsidies on consumption and household income distribution, foreign trade and exchange, monetary and fiscal management, investment and agricultural production.

FEATURE: COLLABORATION IN POLICY RESEARCH: FOOD SUBSIDIES IN EGYPT

In early 1980, discussions were held between Egyptian officials and USAID staff concerning the food subsidy scheme. Among the questions raised were

- What are the full economic costs of the scheme?
- How widespread is access to rationed and subsidized food?
- How are household consumption patterns affected?
- What are impacts on farm households and their decisions about consumption and production?
- What are the effects on foreign trade in the subsidized products and other products?
- Who really benefits from food subsidies? Where do the costs fall?

A project design team was appointed by USAID, and IFPRI was invited to participate. The team developed a research proposal during a three-week visit to Egypt and, most importantly, established contacts with many key Egyptian officials. They included the Deputy Prime Minister for Economic Affairs, the Deputy Minister of Economy, Deputy Ministers of Agriculture and Planning, the Minister of Health, the Director of the Institute of Nutrition, the Director of the Institute of National Planning as well as senior professors at the University of Cairo. These contacts provided a basis for longer term collaboration by involving national policy makers from the very start. They also gave the team the chance to discuss the possibility of collaboration in the actual research with a number of institutes and universities.

In late 1980, letters of agreement were signed with the Institute of National Planning and with the Deputy Minister of Economy. This signing came only after visits by IFPRI's director, project leader and the IFPRI researchers nominated for the project. Two of these researchers had previously undertaken research related to Egyptian agricultural and trade policies. Further discussions were held in the Ministries of Agriculture and Planning, and with the Institute of National Planning. The Deputy Minister of Economy proposed that all contacts with other ministries should be channeled through his office, and this greatly facilitated the contacts with the Ministries of Planning, Investment and Economy, all of which were under the direction of the Deputy Prime Minister for Economic Affairs. Contacts with the Ministry of Supply were strengthened; these proved to be valuable throughout the project, as this ministry plays a key role in the acquisition and distribution of food.

From February 1981 until August 1982, two IFPRI staff members were resident in Egypt receiving logistic support from the Cairo Office of the Ford Foundation. Through a research contract with the Institute of National Planning, a major household survey was conducted covering 3000 households in rural and urban areas of the country.

Following the assassination of President Sadat in 1981, changes were made in the top echelons of government. However, the project had established a wide network of contacts and had sufficient support to survive the political reshuffling with no serious setbacks.

In September 1982, the major analysis commenced in Washington and constant contact was maintained with key ministers and deputies. Drafts of

reports were sent to them at every stage. By July 1983, major pieces of the project were largely complete and the project leader and the three senior researchers visited Cairo for a series of seminars and workshops in the Institute of National Planning. A full day presentation by the project team allowed for discussion of the methods and findings with over 60 people from the Egyptian and expatriate research community and key policy makers. This was followed by a series of private meetings in the offices of the Ministers of Investment and Foreign Cooperation, and Economy; the Deputy Minister of Irrigation and the Under-secretaries in the Ministries of Supply and Agriculture. These small meetings of one to three hours each with the team were conducted in a frank and open manner, and focused on the implications of the findings for a wide range of policy questions related to the food economy of Egypt.

These meetings reflected the interest of the policy makers in the study engendered by the long series of personal contacts that had been made over the preceding three years. The questions being addressed were known to the ministers and deputy ministers prior to the analyses, often having been suggested by them. During these meetings, the policy makers made further suggestions about presentation and further analyses. They were particularly anxious to use the series of studies to make projections about likely outcomes of possible policy changes. Such questions included the linkage between subsidies and wages, alternative methods for targeting, and the distributional consequences of changes in subsidy policy. Further discussions with USAID staff and visits to Cairo and to Washington by Egyptian officials led to a mutually agreed set of policy analyses that were undertaken at IFPRI. The results of these were, in turn, discussed in Cairo by IFPRI staff.

In summary this project has served to highlight several elements essential for effective food policy research. These include:

- the long gestation period required to build a base of confidence and collaboration with national policy makers and researchers;
- the use of a core team of senior, experienced food policy analysts;
- the importance of primary data collection;
- the need to examine many facets (agricultural and fiscal policy, monetary policy and exchange rates, foreign trade), in order to address adequately policy questions related to the food economy of a developing country;
- the need for constant contact with senior officials;
- the contribution to training, to project supervision and to goodwill and confidence that comes from resident staff;
- the role of seminars, workshops and private meetings for ensuring that the results and limitations are clearly understood by the policy makers;
- the flexibility to be able to respond to their suggestions and to conduct follow-up analyses addressing policy alternatives raised by them.

END FEATURE

An immediate and significant contribution of this project was to provide, through a series of publications, a more accurate, timely and comprehensive view than had been previously available of one of the world's largest food rationing and subsidy schemes. Because of its magnitude, the Egyptian subsidy program has attracted much attention and criticism, the latter not always well informed. IFPRI's findings have provided a more solid factual base for assessment of the scheme than had been available. This has been of value not only in Egypt but for all those concerned with the design, funding and execution of subsidy schemes.

At each stage in this project, close contact was maintained with senior officials and seminars were held to discuss preliminary findings, to guide future plans and to present the final results. A measure of the usefulness of the work to policy makers is their requests for additional research and for estimation of the implications or specific options of policy changes identified in conjunction with the researchers. The results of these efforts formed an integral part of the debate about future strategies. As noted, the contribution of an international center to policy making by a national government is to be judged not by the adoption of its recommendations but by the new knowledge which research contributed to national debate and policy making. IFPRI has attempted to ensure that this contribution has been made in the case of food subsidies through its workshops and conferences. In particular, the bringing together of outside analysts and policy makers to share the experiences of over 10 case studies with a broader set of countries has been an effective mechanism for communicating the results of IFPRI research, and providing a forum for exchange between policy makers and researchers.

For these reasons, IFPRI especially has established a wide network of collaborators in ministries of planning, economic policy, development finance and trade, as well as with central banks, producer organizations and universities. These contacts are in addition to work with other international agencies such as UNDP, FAO, WFC, UNCTAD, IMF, IBRD and other centers. Collaboration is facilitated through seminars, study visits and publications and, for instance, IFPRI's research reports have established a reputation for rigor and clear presentation. They often represent a distillation and synthesis of research methods as well as their application to a relevant policy problem. They are being increasingly used in graduate teaching, contributing to the formation of human capital for food policy analysis.

11.4 Coda

* In the past two decades, food production has increased substantially. Even in years of poor harvest, the global supply of food energy has exceeded the arbitrary levels of average per capita requirements by a significant margin.

* The gains have been unevenly distributed across countries and regions, and through time. The contribution of new agricultural technology has been uneven and the rate of growth of food consumption has been much lower and more variable in some countries than in others.

* It is increasingly clear that greater food production is neither a necessary nor a sufficient condition for a given country to improve either the level or reliability of food consumption.