ICRISAT in the Eighties

A 10-year Plan

ICRISAT
International Crops Research Institute for the Semi-Arid Tropics

Contents

1. Background 1

   1.1 The Mandate 1
   1.2 The Basis for the Mandate 1

2. ICRISAT's 10-Year Priorities and Goals 5

   2.1 The Target Groups 5
   2.2 The Client Groups 5
   2.3 Geographic Areas of Concentration 7
   2.4 Priorities Among Programs 8

3. Research Priorities 9

   3.1 Crop Improvement Strategies 9
   3.2 Crop Improvement Priorities 9
      Sorghum 9
      Pearl Millet 14
      Pulses 20
      Groundnut 26
      Genetic Resources 32

   3.3 Resource Management Research 34

      Farming Systems 34
      Economics 39

4. Transfer of Information and Technology 43

   4.1 Training 44
   4.2 Workshops, Seminars, and Conferences 46
   4.3 Information and Library Services 47

5. Organization and Cooperation 47

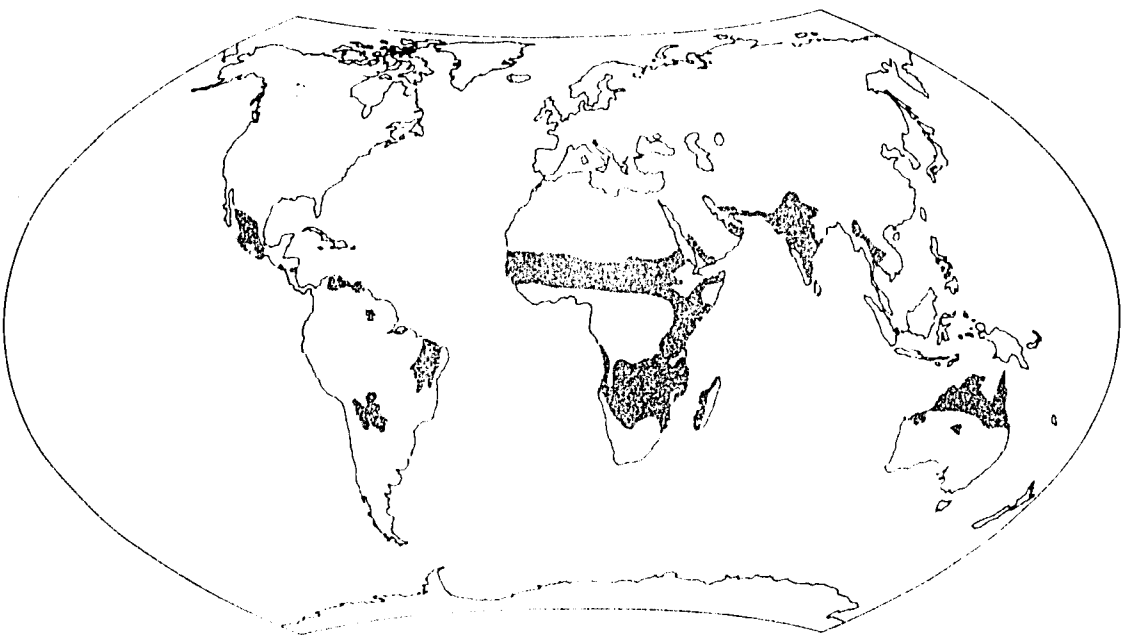
   5.1 Organization at ICRISAT Center 47
   5.2 Research Projects 51
   5.3 Network for Core Program Research in India 51
   5.4 ICRISAT Network in Africa 52
   5.5 Cooperative Linkages 54

6. Resources 56

   6.1 Staffing Guidelines at ICRISAT Center 56
   6.2 Staffing Guidelines in the Cooperative Program 56
   6.3 Non-Salary Costs 57
   6.4 Capital Requirements 57
   6.5 Resource Requirements Over the First 5-Year Period 58

Conclusion 60

Figure 1. The semi-arid tropics (shown in brown).



ICRISAT IN THE EIGHTIES: A 10-Year Plan

1. Background

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) was created by the Consultative Group on International Agricultural Research (CGIAR) in 1972 on the recommendation of its Technical Advisory Committee. It was the first new research center established by this informal association of governments and foundations brought together in 1971 by the World Bank, FAO, and UNDP to increase food supplies in developing countries.

1.1 The Mandate

The mandate of ICRISAT is to:

1. Serve as a world center for the improvement of grain yield and quality of sorghum, millet, chickpea, pigeonpea, and groundnut and to act as a world repository for the genetic resources of these crops.

2. Develop improved farming systems that will help to increase and stabilize agricultural production through more effective use of natural and human resources in the seasonally dry semi-arid tropics.

3. Identify constraints to agricultural development in the semi-arid tropics and evaluate means of alleviating them through technological and institutional changes.

4. Assist in the development and transfer of technology to the farmer through cooperation with national and regional research programs, and by sponsoring workshops and conferences, operating training programs, and assisting extension activities.

1.2 The Basis for the Mandate

The Semi-Arid Tropics (SAT)

Following Troll's classification, the semi-arid tropics are areas where monthly rainfall exceeds potential evapotranspiration for 2 to 7 months and the mean monthly temperature is above 18°C. The areas with 2 to 4½ wet months are called dry semi-arid tropics and those with 4½ to 7 wet months are called wet-dry semi-arid tropics.The semi-arid tropics comprise all or part of 49 countries on five continents (Fig. 1). The total area is around 19.6 million km², supporting a population of more than 700 million people. Of the 49 countries, all but Australia are classified as less developed.

The Indian subcontinent has the largest semi-arid tropical area of any of these developing countries—about 10% of the total SAT. But on a regional basis, the largest geographical areas lie in West Africa (24%), East Africa

Annual compound growth rates of production of ICRISAT crops from 1961-65 (average) to 1978[a].

Region	Sorghum	Pearl Millet	Chickpea	Pigeonpea	Groundnut
WORLD	2.82	1.25	0.68	0.93	0.77
Semi-Arid Tropics	3.82	1.05	0.57	0.91	0.18
West Africa	0.67	1.01	N.D.	N.D.	-4.02
East Africa	2.68	2.88	-0.67	9.10[b]	9.20
Southern Africa	2.04	-0.51	N.D.	1.30	1.81
South Asia	1.64	1.32	0.72	0.85	1.67
West Asia	-3.11	-4.99	-2.90	N.D.	N.D.
Other Asia	2.65	-1.14	0.81	0.03	1.75
Latin America	11.98	3.87	-4.20	-4.82	-2.49

a. Sources: For World, up to 1975, FAO computer data tape. From 1976-78, FAO Production Year Book 1979, Vol. 33. For semi-arid tropics and its regions ICRISAT computer printouts (derived from FAO data).

b. Data from 1967 to 1978.

(22%), southern Africa (20%), and Latin America (19%). India has by far the largest total population in the SAT, more than 400 million people or 55% of the total. Next are the countries of West Africa (13%), Latin America (11%), southern Africa (5%), other Asian countries (8%), and East Africa (8%).

The Mandate Crops

Sorghum and pearl millet are the fourth and fifth most important cereals of the world. Together they rank second to rice in cultivated area in developing countries. Generally, they are the cereals of the poorest countries and the poorest people in those countries. In assessing priorities in 1975 the Technical Advisory Committee of the CGIAR (TAC) drew attention to the fact that cereals contribute some 70% of overall energy supplies in human diets in developing countries. Sorghum and millets together rank first, among cereals, in calorie intake in Africa and third in Asia. Among the millets, pearl millet is the most important in the SAT and thus requires major attention. The minor millets such as foxtail millet (*Setaria italica*) and finger millet (*Eleusine coracana*) are important regionally in some SAT situations.

The demand for these cereals is also increasing in the developed countries where they are used for animal feed. Sorghum, particularly, is becoming an important export item and earner of foreign exchange for the developing countries and a source of cash for producers.

World sorghum production has been growing at a compound annual rate of about 2.8% since the early 1960s, while production in the semi-arid tropics has

grown somewhat faster at 3.8% per year. Over the same period world pearl millet production has grown at less than 1.3% per year. Production growth of pearl millet in the semi-arid tropics has lagged behind that in other regions and stands at just over 1% per year.

The World Bank and the World Food Council both project that demand for coarse grains in developing countries will grow at a rate of around 3.6% per year up to the end of the century. This is far in excess of the historical growth rates of world sorghum and pearl millet production.

Although historical sorghum production growth in the semi-arid tropics exceeds the projected demand growth in developing countries, there are major regional imbalances. In West Africa over the last 20 years sorghum production has been growing at a rate of only 0.7% per year. In southern and eastern Africa over the same period sorghum production has been growing at less than 2.7% per year, and in India at just over 1.6% per year.

Among the major pearl millet growing regions in the semi-arid tropics, southern and West Africa have had the poorest production records. In the former, production has been declining at 0.5% per year and in the latter a growth rate of around 1.0% per year has been experienced. India and eastern Africa have had somewhat better records although their growth rates of 1.3 and 2.9% per year, respectively, are well below projected demand growth.

It seems clear that the developing countries within ICRISAT's mandate region will experience either increasing shortages of sorghum and pearl millet at present prices or, more likely, much higher prices and large numbers of low-income people with unmet food needs. One estimate from the USDA is that unmet food needs in sub-Saharan Africa could be between 9 and 13 million tonnes by 1990.

Chickpea and pigeonpea are the most important pulse crops of the developing world and of the semi-arid tropics, mainly because they are first and second in importance in the Indian subcontinent, which produces 80% of the chickpeas and 95% of commercial pigeonpeas.

Chickpea is an important crop throughout West Asia, around the Mediterranean Sea, and in parts of East Africa and Latin America. A growing market in the United States for chickpea is supplied principally from the semi-arid regions of Mexico. Pigeonpeas are grown throughout the SAT, particularly in East Africa, in Central America, and wherever people of Indian origin have settled around the world. Forty-nine countries currently exchange pigeonpea germplasm with ICRISAT.

Demand for pulses in the developing world is projected to grow at a compound annual rate of between 2.3 and 2.7% to the year 2000. In India, production of chickpea has been growing at an annual compound rate of only 0.7% from the early 1960s to 1978. During the same period world chickpea production has been growing at about the same rate. Production has been declining at almost 2.9% per year in the SAT countries of West Asia and by 0.7% in eastern Africa. World pigeonpea production has been growing at an annual rate of 0.9% over the same period. The growth rate of pigeonpea production in India has been less than 0.9% per year.

The above figures suggest that there will be a major production shortfall in pulses in the semi-arid tropics, especially in India, if these trends continue.

Groundnut is the most important oilseed crop of the semi-arid tropics. Areas in excess of 100,000 ha are planted to groundnuts in 24 countries, 95% of which are less developed countries. As a combined oilseed and food crop, groundnut ranks second only to soybeans, and it is the most important oilseed in the developing world. In 1979/80 India alone spent approximately US $800 million on the import of vegetable oils.

The projected deficit between demand for oilseeds and supply in developing countries in 2000 is alarming. Demand is expected to grow at a compound rate of about 3.9% annually. Groundnuts, a major source of vegetable oil in the semi-arid tropics, has had a poor production record in the region and has grown at less than 0.2% a year. In semi-arid West Africa groundnut production has been declining at a rate of more than 4.0% annually. India's record is not as bad but its growth rate of 1.6% is well below projected demand growth.

To meet the challenge of these projected deficits of cereals, pulses, and oilseeds in ICRISAT's mandate region, we must identify and develop technological improvements that will enhance the growth in productivity.

Technological and Socioeconomic Constraints in Rainfed Agriculture

Traditional agricultural systems in rainfed SAT areas have evolved over a long period to provide something to eat in all but the worst years. The technology is based on the use of traditional varieties and tools and human or animal labor, whichever is available. A high economic return is not the major goal and there are many technological and socioeconomic constraints to maximum food production.

Because of the largely undependable distribution of rainfall, diversified cropping is the rule, the ecological balance is precarious, livestock/cropping interactions are significant and complex, and what infrastructure is available has a considerable influence on the cropping decisions made by farming families. The vast majority of farmers in the SAT are of limited means and can ill afford the cost of technological mistakes. Technology options that involve greater-than-average risks must have large economic rewards to make them attractive to farmers. Our mandate requires research on the technological and socioeconomic aspects of the farming systems within which farmers must operate, and only within which crop production can be increased through the transfer of technology.

Agricultural research in the developing countries of the SAT has generally been aimed at increasing production of commercial crops. Our concern is for food crops in rainfed agriculture in less dependable rainfall areas. The gap between the income of people in irrigated areas and rainfed regions has been growing. Moreover, governments are realizing that the potential of the semi-arid tropics to produce food far exceeds present production levels. The potential for modern agriculture does exist.

The Transfer of Technology

A limiting factor in the process of the communication of research findings to client groups is the lack of scientifically trained manpower in many SAT national research and development programs. The relatively few scientists and skilled agricultural staff already at work are restricted in their access to new technology, literature, and germplasm. There is a need to reduce their isolation and increase their perspectives and their knowledge of methodologies, including the selection of cultivars for adoption on-farm. This can be done through training and conferences, improved communications and by expanding our outreach programs.

2. ICRISAT's 10-Year Priorities and Goals

2.1 The Target Groups

Over the next 10 years ICRISAT's priority target group will continue to be the small farmer of limited means farming his land with few inputs and without the benefit of regular irrigation, but with the help of his family and some landless labor. We include all these dependents, plus other villagers who supply the farmer with goods and services and receive food and payment from him in return, within the primary target group.

In the rainfed semi-arid tropics virtually all farmers are small farmers in the sense described above. ICRISAT serves the small farmer best by devising means to increase the productivity and stability of his major food staples and improving the efficiency of his use of water, capital, and other scarce resources. His staple food crops must be of good quality, be resistant to major diseases and pests, tolerant to the common stresses of the SAT, responsive to inputs and good management and capable of giving fair yields under low inputs and poor management.

While the small farmer and his dependents are our primary target, they are not our sole target group. The CGIAR has endorsed the first priority objective of its Technical Advisory Committee (TAC) of ensuring adequate food supplies in the developing world. ICRISAT, thus, must be able to provide breeding materials and suitable cultivars of its mandate crops to all who endeavor to fulfill this basic objective. Similarly, while our crop improvement mandate is focused upon the semi-arid tropics, it is not restricted to the SAT. Producers of our mandate crops may benefit from our research wherever these crops are grown.

2.2 The Client Groups

National Scientists

ICRISAT's immediate clients, the direct users of our outputs, are the scientists of national institutions in the SAT countries. National scientists are responsible

for producing improved cultivars and new technologies for the farmers of their countries; ICRISAT undertakes research that contributes and compliments their efforts. Our regional and cooperative programs are aimed at strengthening their research institutions and programs. From workshops and conferences we obtain their assistance in planning our research. National research scientists and their technicians comprise most of our trainees.

We emphasize in our research what national scientists cannot or do not do. We introduce genetic diversity by bringing together at one place a substantial germplasm collection, including most of the natural landraces that are available, and incorporating this diversity into the breeding materials that we make freely available. We offer them advanced materials through our network of international trials.

We develop new methods of plant breeding, or improve old methods for new situations. We emphasize resistance to widespread diseases and the worst pests and tolerance to major stress factors such as drought and poor soils. We try to pursue difficult problems with great concentration and with sufficient resources.

We utilize and demonstrate a multidisciplinary team approach incorporating the physical, biological, and social sciences.

National Research Programs and Institutions

In India, the scientists in our client group work mainly in the state agricultural universities in nationally coordinated programs. We have established cooperative agreements in crop improvement research with universities in Tamil Nadu, Karnataka, Madhya Pradesh, and Haryana. We will continue to assist in strengthening these institutions.

In Nigeria, ICRISAT cooperates with the well-equipped Institute of Agricultural Research at Ahmadu Bello University. In other African countries where we have cooperative programs, the national scientists work in government research agencies. Where these agencies are short of facilities or land suitable for research, ICRISAT has built facilities and developed research farms. Some ICRISAT scientists have been stationed in those agencies largely to serve the national research efforts. These aspects of our work are likely to diminish over the next 10 years as others assume the role of institution building and national scientists are trained and appointed.

Extension and Action Agencies

In African countries more than in India, we will produce finished varieties of sorghum and millet. Most countries south of the Sahara do not yet have sufficient numbers of trained personnel to develop extensive networks of research and, for a few more years, ICRISAT scientists employed through cooperative programs must function partly as national scientists in these countries. The varieties and improved practices they require are taken by extension agencies and tested on farmers' fields. We assist in establishing and evaluating the trials.

Our farming systems research has substantial demonstration value. Improved technology for deep Vertisols in the semi-arid tropics of India has reached the stage where it is being tested on-farm and in pilot projects. ICRISAT will advise extension and action agencies that wish to use this technology. Training is being given to state agricultural officers, bank agricultural advisers and voluntary agencies, so that they may then implement the technology more widely through the country.

The ICRISAT Governing Board has established a Transfer of Technology Committee to determine which research results can be appropriately transferred through training program, conferences, workshops, and cooperative programs with national institutions.

2.3 Geographic Areas of Concentration

Of the two major divisions in the SAT—the dry and the wet-dry semi-arid tropics—ICRISAT will concentrate its efforts in the former, that is, in the region with 2 to 4½ wet months in the year. However, some work on sorghum and the leguminous crops will be done to directly benefit the wet-dry region. We hope also to improve our cooperative relations with other research agencies working particularly for this region.

Over the next 10 years ICRISAT will develop a larger regional program. Regional groupings of participant countries have been developed for each crop, and priorities of and for each region have been established by consultation with national scientists and by statistical and program analyses within ICRISAT. All regional programs will be developed with the guidance and cooperation of relevant national institutions and programs. South Asia will be a first priority region for sorghum, pigeonpea, chickpea, and groundnut. Subregions within this region have also been identified.

ICRISAT is concerned about declining food production in West Africa and intends to make a serious attempt to introduce new plant materials and technologies that can be used to arrest this trend. West Africa will be the first priority region for pearl millet and a high priority region also for sorghum, groundnuts, and associated farming systems and economics programs. It will be served from ICRISAT's Sahelian Center in Niger and other regional locations in Upper Volta and Nigeria.

Eastern and southern Africa will have next claim upon our attention. ICRISAT crops are or have been important food crops in these regions, and there is clear recognition that maize production has been extended beyond the crop's agroclimatic limits. Sorghum and millets can offer safer and culturally acceptable alternatives if modern input-responsive cultivars can be made available. The Heads of State of nine southern African countries have asked ICRISAT to establish a regional center and we will respond specifically in relation to sorghum, pearl millet, groundnut, and dryland farming systems. Eastern Africa will be a priority region also for pigeonpea and to a lesser extent chickpea.

West Asia and the Mediterranean are important chickpea-producing areas. ICRISAT is serving this region directly by stationing its scientists at ICARDA in a cooperative research program.

ICRISAT crops are important also in Latin America. Sorghum has potential as a food crop for small farmers in Mexico and Central America, where pigeonpea is also important. Sorghum and millet have considerable potential for feedgrains and forages throughout the region. ICRISAT will serve this area mainly through cooperative agreements with U.S. universities, but some direct input from ICRISAT Center will be necessary. Pulse yields in particular must be substantially improved to reach production technology levels relevant to South American economic conditions.

The region of Southeast Asia and the Pacific is important for sorghum, groundnut, and pigeonpea. It will be served mainly from ICRISAT Center and through cooperative agreements with such other agencies as the ESCAP/FAO Center for Coarse Grains, Pulses, Root Crops, and Tubers in Indonesia.

2.4 Priorities among Programs

After 10 years of growth the priorities among programs are well established and can be judged from current core and special project budget presentations. The global sorghum improvement program is and will continue to be the largest in funds and numbers of principal staff. Pearl millet and groundnut have programs of about equal size, and the programs in pigeonpea and chickpea, which are combined into a single Pulse Improvement Program, are somewhat smaller.

The Farming Systems Research Program is larger than the sorghum program, but this relation may change over the next 10 years. The program in Economics is about the same size as the program for each pulse crop. It is a large program in social sciences by IARC standards made necessary by the many economic and social constraints affecting small farmers in rainfed agriculture.

Training at ICRISAT is given substantial importance, particularly because of the dearth in trained people in the semi-arid tropics outside of India, and because the transfer of farming systems technology, which has high site-factor and complexity constraints, requires intimate knowledge of all aspects of all the practices involved.

Genetic Resources requires substantial input because of the several crops for which ICRISAT acts as the primary collector and repository.

The order of priorities are in general agreement with priorities accepted by the CGIAR in its review of the TAC Paper on Priorities (1980). Forward projections for all programs over the next 10 years assume limited growth mainly through increases in core program resources. A separate section in each program narrative discusses changes in priorities under other growth assumptions.

3. Research Priorities for the Eighties

3.1 Crop Improvement Strategies

Our crops are often subsistence crops and are frequently grown by small farmers with few inputs under rainfed conditions. The risks involved in making monetary inputs for fertilizer and pesticide are high. In these circumstances, the small farmer needs stable, pest-resistant or tolerant cultivars with yields consistently higher than traditional varieties under traditional management and responsive to whatever improved levels of management he can provide.

One of the serious limitations to increasing yield potential under the harsh environments of the SAT has been the narrow germplasm base. Variability will be increased by introducing additional germplasm resources and breeding stocks from other areas.

We will emphasize resistance to major diseases and pests and tolerance to major stresses, and ensure that these factors are durable and that yield potential is retained. This involves developing screening techniques for identifying broadly-based genetic resistance and tolerances, incorporating them into elite breeding material, and screening such material in many situations, including contrasting levels of farming.

Improving quality of the mandate crops is a major goal of ICRISAT. Emphasis in earlier years has been on nutritional quality. This work will continue but emphasis will include quality in storage and consumer preferences particularly of taste and cooking quality.

We realize that outputs of breeding material must be selected so as to be easily incorporated into national breeding programs and yet contain sufficient variability to allow adaptation to local situations. ICRISAT scientists at regional stations can make a direct input into national research programs by way of providing varietal material, participating in evaluation, and providing service activities such as regional crossing programs. We may cooperate in agronomic research to exploit the potential of currently available and new cultivars, and in cropping system and crop management technologies.

3.2 Crop Improvement Priorities

Sorghum

yields of sorghum (*Sorghum bicolor* [L.] Moench) in the SAT are kg/ha compared to 3400 kg/ha in non-SAT high technology

ICRISAT's Sorghum Improvement Program began in 1973 with a strong input into population improvement. Derived lines now contribute to national breeding programs around the world, as do varieties developed in the grain mold resistance/food quality program, which was started a little later.

Initially a major effort was made to develop resistance to shoot fly. Much has been learned about the insect and its ecology; a useful screening procedure has been developed, and several traits contributing to resistance have been identified. Varieties are now available in a reasonable agronomic background with increased levels of resistance. Stem borer is of major importance: rearing and infesting techniques are now available, and sources of resistance are being identified. An effort is being made to improve our capability to screen for midge and headbugs.

A useful consistent procedure to screen for grain mold has been developed, and virtually all of our breeding projects have material in this program. Procedures to screen for resistance to downy mildew and charcoal rot are being developed, and a screening program for resistance to anthracnose and other leaf diseases has begun.

Progress has been made, both in developing screening procedures and in learning more about control-management techniques for the parasitic weed *Striga*. This work is going on both in West Africa and at ICRISAT Center since different species of *Striga* exist in Africa and India.

Progress has been made recently to screen for aspects of drought and heat tolerance and stand establishment. Generally breeders have developed early drought-escaping varieties; we can now evaluate other mechanisms leading to resistance.

In breeding for high lysine and better food quality grain, we used two sources of high lysine: one, a shrunken-seeded type from Ethiopia and another, an opaque from Purdue University. There has been a problem developing high-lysine varieties with acceptable normal grain. It is now clear, as with opaque-2 maize, that the solution to this problem will require a substantial investment in research. A team of scientists has been involved with this and related problems at Purdue University for many years; we are liaising closely with the University. To maintain focus on yield and stability with good quality of grain, ICRISAT has shifted emphasis to determine food quality preferred by consumers in Asia, Africa, and Latin America. We have made considerable progress in this direction.

Priority Regions

With substantial input from sorghum breeders throughout the world, and particularly from within the semi-arid tropics, we have identified functional geographic regions, zones of adaptation, and priority problems for sorghum improvement. Geographic functional regions are areas of such a size that coordination of research is recommended. They are listed in Table 1, with overall importance being placed on the Indian subcontinent, western Africa, eastern Africa, southern Africa, Central America, and Mexico. While the SAT zone produces sorghum primarily for human consumption, the non-SAT zone (except China) produces it mostly for animal feed. There are noticeable trends of increase in demand from some areas (Latin America, East Africa) for sorghum as direct human food, particularly in areas that are marginal for the production of maize.

Table 1. Geographical regions including area under sorghum, and yield.

Functional region	Area (Million ha)	Average yield (kg/ha)	Relevant major collaborators
PRIORITY 1			
Indian subcontinent	16.6	784	ICAR and agricultural universities
West Africa, low to intermediate rainfall areas (Nigeria, Senegambia, Sudan, Mali, Upper Volta)	13.4	654	Research agencies in region such as USAID, IRAT, FAO, IDRC, ICIPE, INTSORMIL, and many national programs
West Africa, high rainfall areas	22.9	655	Developing research programs by SAFGRAD, CILSS, Institut du Sahel
Eastern Africa and Yemen (Ethiopia, Kenya, Tanzania, Yemen, etc.)	6.2	956	
Southern Africa (Zimbabwe, Mozambique, Malawi, Botswana, etc.)	0.8	758	
Central America and Mexico (Mexico, El Salvador, Gautemala, Honduras, etc.)	1.9	1655	INTSORMIL and national programs
PRIORITY 2			
Tropical South America	0.65	2171	INTSORMIL and national programs
Far East	8.6	1043	
Southeast Asia	0.5	1183	
Mediterranean - USSR			
Contributing Regions			
Temperate America	7.9	2508	National programs
Oceania (primarily Australia)	0.4	1812	

Source: Adapted from FAO Production Year Book, Vol. 32, 1978.

Zones of adaptation have been identified within geographic functional regions. They are defined roughly by rainfall and length of rainy season (low, intermediate, high), latitude (temperate, tropical), and elevation (low, intermediate, high). Movement of sorghum within similar zones of adaptation, within or across geographic functional regions is expected to result in similar crop

performance, i.e., good correspondence. However, correspondence would not be expected to be as good between different zones of adaptation. The core program cannot respond to the problems of all these areas but will address itself to the major problems of the Priority 1 regions and will interact with the other regions. Some agencies with which cooperative activities are already taking place or could occur are listed in Table 1. Correspondence of material developed at ICRISAT has been best in the intermediate elevation areas of East Africa, in lower elevation areas of Central America, and the low and intermediate rainfall areas of West Africa. It has not been so good in high rainfall areas of West Africa or high elevation areas of East Africa (Ethiopia) and Central America. ICRISAT materials have begun to contribute in the Far East (China), but selection for adaptation is needed.

Research Priorities, Strategies, and Goals

Research priorities have been identified for the various zones of adaptation for each geographic functional region and are shown in Table 2. The following problems will be addressed:

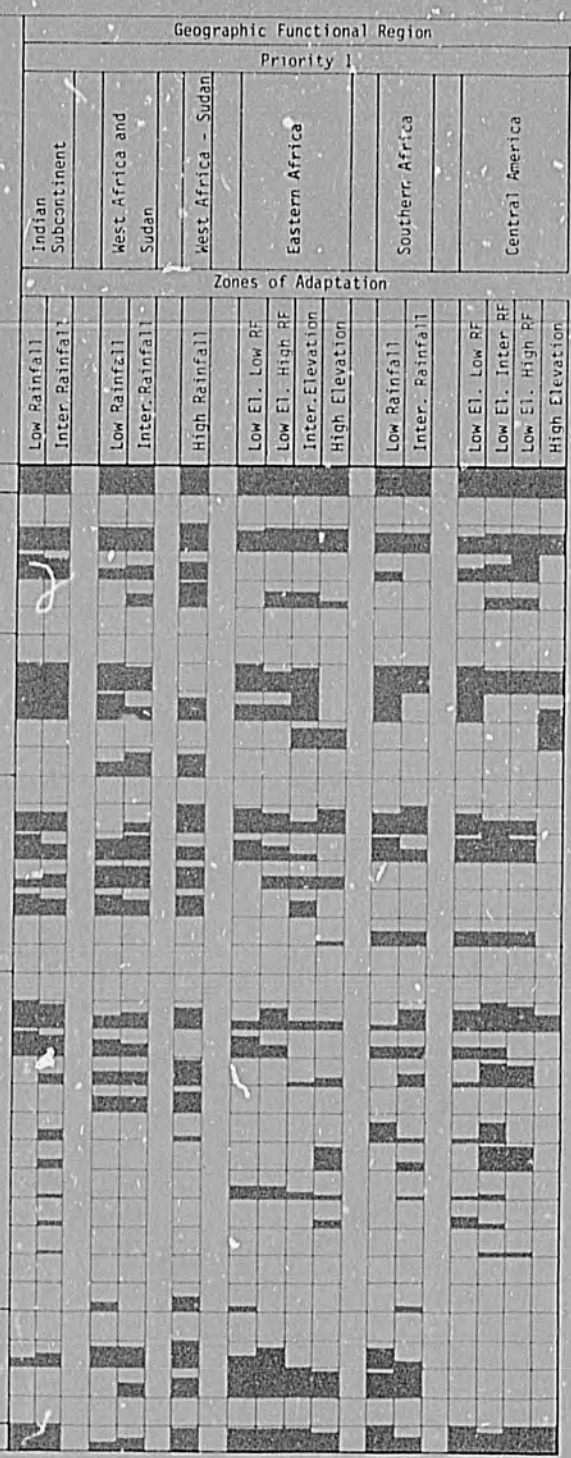
1. Breeding varieties and hybrids with good levels of yield and stability. The major thrust of our research is to assist poor farmers in areas of limited rainfall, but a significant effort will also be made for situations of adequate moisture where high yields justifying inputs is possible.
2. Improving management systems for adequate and limited moisture situations and evaluation of material specifically for intercropping in cooperation with Farming Systems scientists.
3. Developing techniques for identifying source material and incorporating resistance traits into agronomically elite lines for biotic and abiotic stress situations.
4. Perfecting techniques to evaluate basic food preparations, and learning more about factors contributing to quality. Breeding stocks will be evaluated for food traits.
5. The program will be dynamic and interdisciplinary. It will draw upon and contribute to the advances being made under the USA Title XII project (INTSORMIL), the All India Coordinated Sorghum Improvement Project, and national programs of other countries.

Funding Implications

If funding improves, we will expand our international network of activity in several geographic functional regions. We will also increase our research activities into cytoplasmic factors related particularly to male sterility and the question of genetic vulnerability and into apomixis as it relates to vegetative production through seed of F_1 hybrids. We will try to capitalize on nitrogen fixation activity in sorghum and, if the situation justifies, we will increase our input into breeding for high nutritional quality of the grain.

If funds decline we will reduce research in some of the leaf diseases. A decreased input in breeding at ICRISAT Center is possible if this activity is

Table 2. Distribution of priorities for sorghum improvement by geographic function region and zone of adaptation.



*The height of the black box is proportional to the priority placed on a trial in a particular zone of adaptation.

strengthened in other geographical regions through core or special project funding.

Linkages with Other Institutions

There is growing cooperation between the sorghum improvement programs of ICRISAT and INTSORMIL. During the 1980s this cooperation should considerably strengthen, particularly in Central and South America and parts of Africa. There is a cooperative program for entomology with the Centre for Overseas Pest Research in the UK and the Max-Planck Institute. Additional linkages are indicated in Table 1.

Pearl Millet

Of the several millets, pearl millet (*Pennisetum americanum* [L.] Leeke) is the staple cereal best suited to the harsh climate of the hot, drought-prone, dry semi-arid regions of Africa and the Indian subcontinent. It is the only millet that ICRISAT will include in its crop improvement program to any significant extent in the next 10 years. Though the farmers' average yields are 500 to 600 kg/ha over the 26 million ha grown, our researches have shown that these yields can be increased three to five times with improved cultivars and moderate inputs.

In the last 8 years ICRISAT scientists have developed a deeper understanding of the problems of substantially improving pearl millet yield and have developed techniques of managing some important yield-reducing factors.

The most significant achievements have been:

- Generating a broad base of diverse breeding material that combines high yield potential and resistance to downy mildew, and distributing it extensively to the national programs, particularly in India.
- Developing and releasing open-pollinated varieties produced by recurrent selection from breeding populations that are less susceptible to downy mildew and ergot. These varieties have given over 98% of the yield of existing commercial hybrids.
- Developing and transferring to national programs large-scale field screening techniques for reliably selecting resistances to downy mildew, ergot and smut and distributing material with single and multiple resistances.
- Showing that at low to medium yield levels, grain protein content can be improved without impairing selection efficiency for increased grain yield.
- Showing that rhizosphere nitrogen fixation can be important in pearl millet.
- Developing and utilizing international cooperative networks to test the stability of disease resistance and the adaptability of breeding products.
- Developing some understanding of tolerance to environmental stresses, such as drought, and testing methods for breeding for such situations.

Priority Regions

The major pearl millet growing areas of the world can be divided into four zones, all in less developed areas of the semi-arid tropics. Two zones I and III have relatively high priority (Table 3 and Figs 2 and 3). Within zone I there are several Sahelian countries that depend on pearl millet as a staple cereal and they face the possibility of a chronic food shortage in the next decade.

Research Priorities, Strategies, and Goals

The major thrusts in research will continue to be problem-oriented, and products will be developed through interdisciplinary work.

1. Environmental stress

In studies on environmental stress, the first thrust will be in developing screening and breeding techniques for improving resistance to moisture stress. Some progress has been made, and this work should be completed by 1985. The techniques will be routinely used in breeding hybrids and varieties to withstand moisture stress situations.

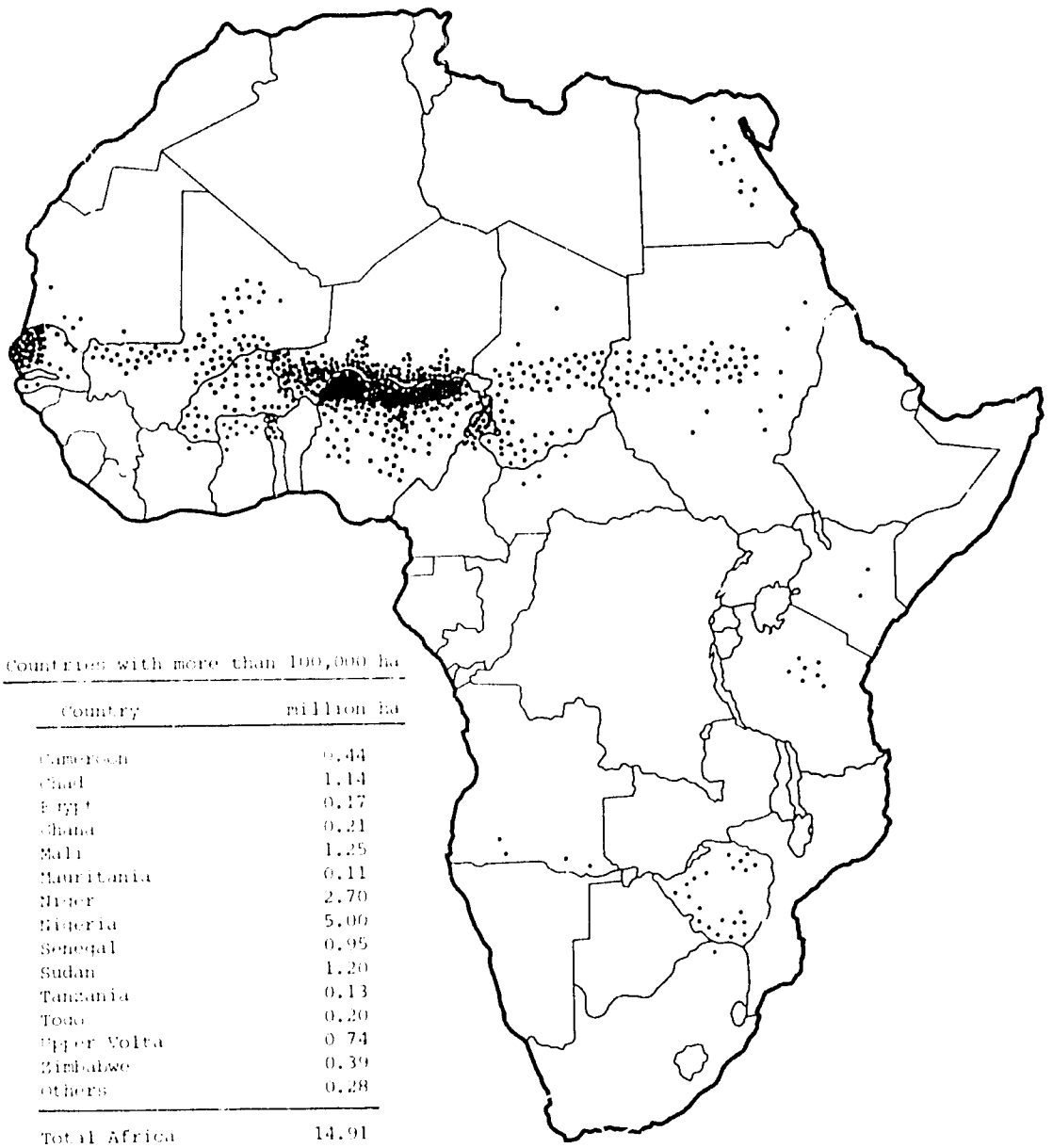
Table 3. Geographic areas/functional zones of pearl millet production (1978 data base).

Zone	Priority	Area (million ha)	Average yield (kg/ha)	Major collaborators
I. Sahelian Africa				
Cameroon, Chad, Mali, Mauritania, Niger, Nigeria Senegambia, Sudan, Upper Volta	1	13.53	520	UNDP, USAID, SAFGRAD, CILSS, IRAT, Inst. du Sahel, IDRC and national programs
II. Southern and Eastern Africa				
Botswana, Egypt, Tanzania, Zambia, Zimbabwe	3	0.69	500	
III. N. India & Pakistan				
Gujarat, Haryana, Madhya Pradesh, Punjab, Rajasthan, Uttar Pradesh, & Pakistan	2	8.39	430	
IV. Central & South India				ICAR and universities
Andhra Pradesh, Karnataka, Maharashtra, Tamil Nadu	4	3.31	420	

Source: FAO Production Year Book, 1978, Indian Agriculture in Brief, 17th ed., 1978, World Agricultural Atlas, Vol. IV (Africa), 1976, Bajra Production in 1976, Pakistan Agricultural Research Council.

Figure 2. Reported area planted to pearl millet in Africa (1978), priority 1 zones in brown.

One dot equals 20,000 hectares

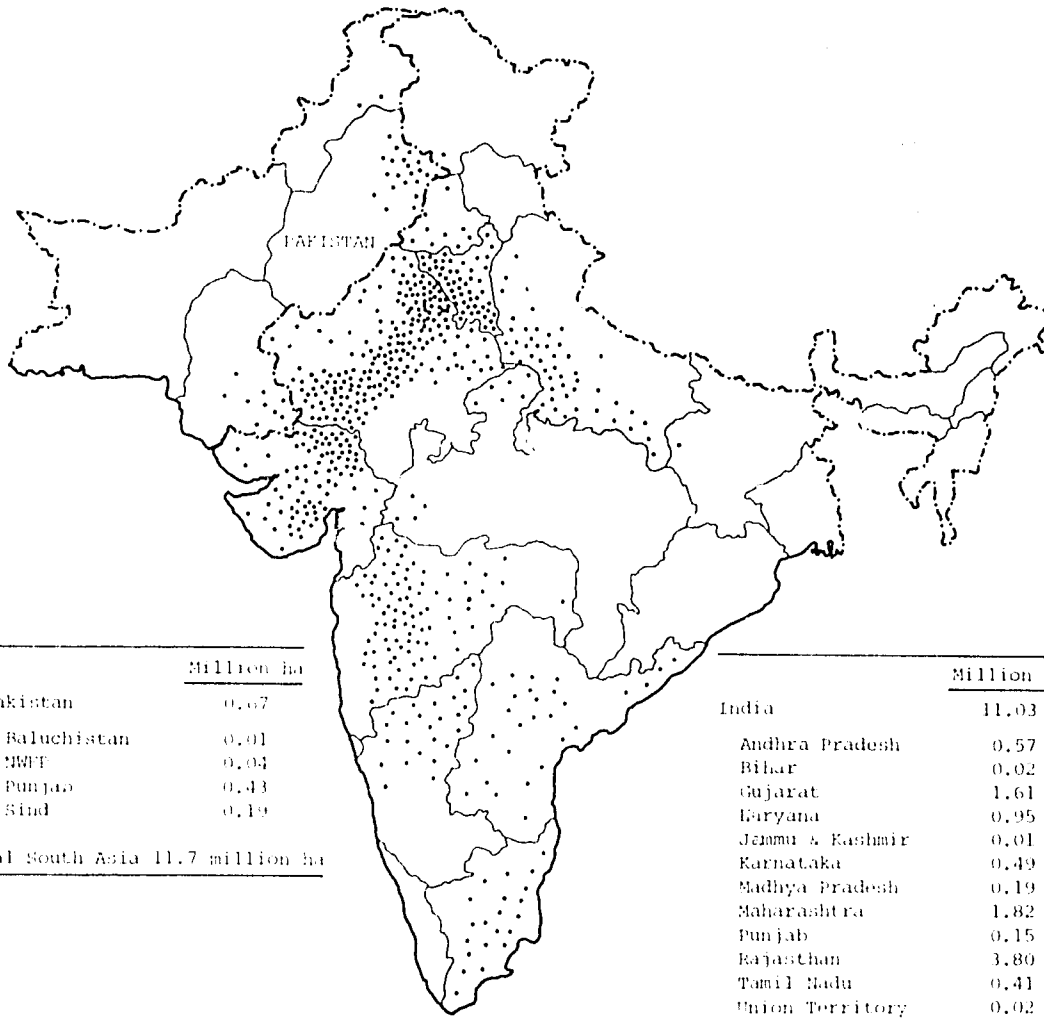


Countries with more than 100,000 ha

Country	million ha
Cameroon	0.44
Chad	1.14
Egypt	0.17
Ghana	0.21
Mali	1.25
Mauritania	0.11
Niger	2.70
Nigeria	5.00
Senegal	0.95
Sudan	1.20
Tanzania	0.13
Togo	0.20
Upper Volta	0.74
Zimbabwe	0.39
Others	0.28
Total Africa	14.91

Figure 3. Reported area planted to pearl millet in South Asia (1978), priority 2 zones in brown.

One dot equals 20,000 hectares



	Million ha
Pakistan	0.67
Baluchistan	0.01
NWFP	0.04
Punjab	0.43
Sind	0.19
Total South Asia 11.7 million ha	

	Million ha
India	11.03
Andhra Pradesh	0.57
Bihar	0.02
Gujarat	1.61
Haryana	0.95
Jammu & Kashmir	0.01
Karnataka	0.49
Madhya Pradesh	0.19
Maharashtra	1.82
Punjab	0.15
Rajasthan	3.80
Tamil Nadu	0.41
Union Territory	0.02
Uttar Pradesh	0.99

The second thrust will be in understanding the factors responsible for poor crop establishment that can be ameliorated by genetic improvement and/or by soil management; this may take 3 to 5 years.

The third thrust will be in investigating the implications for breeding strategies to improve crop performance under low fertility because of its relevance to conditions under which pearl millet is grown and will continue to be grown by resource-poor farmers. We will study the role of mycorrhizae (fungus invasion of roots) in enhancing nutrient uptake in low-fertility conditions.

2. *Nitrogen fixation*

To exploit the finding that pearl millet roots support bacteria which fix nitrogen, we need to refine assay techniques to satisfactorily screen varieties/lines for this capacity. We hope that by 1985 techniques will permit reliable selection for nitrogen-fixing capacity so it can be bred for. Studies will also be made on how environmental conditions affect the performance of the nitrogen-fixing association and the nature of the crop/organism interaction.

3. *Disease stress*

Downy mildew and ergot have proved major hazards to using higher-yielding genotypes, particularly hybrids. Grain smut and rust also have the potential to become epidemic in pearl millet. To ensure that the correct strategies are developed for the utilization of genetic resistance—and other possible methods of control--the biology and epidemiology of all four diseases, particularly downy mildew, ergot, and smut, will receive attention over the next 7 to 10 years. Special attention will be given to the identification and development of resistances effective against different races of downy mildew and to different levels of disease pressure as observed in West Africa.

The ergot resistance that has been developed is primarily needed in hybrids, but as it seems that resistance factors must be bred into both parents of a hybrid, the development of resistant hybrids may take some time.

Screening for resistance to smut and rust will continue, and effective levels of resistance will be incorporated in advanced breeding material but on a second-priority basis.

4. *Insect pest stress*

On the Indian subcontinent, pests have thus far been relatively minor hazards to production; therefore, activities in entomology will be limited to surveillance. In Africa, however, stem borers and earhead pests can cause serious damage and need attention; entomologists will determine the extent and severity of these pests and attempt to develop techniques to screen for genetic resistance.

5. *Breeding for high yield and resistance to stresses*

The pearl millet breeders will intensify their efforts to increase yield potential while incorporating resistance to those factors that reduce yield and contrib-

ute to instability of production. Major objectives are to incorporate into advanced breeding material sources of resistance to drought and disease, efficient use of low levels of soil fertility, and possibly capacity to stimulate nitrogen fixation. Utilization of germplasm is fundamental to most of these activities. ICRISAT has an extensive and still expanding germplasm collection that is a major source of unexploited variability. The systematic mobilization and dissemination of germplasm variability through crossing and progeny selection will be a priority objective in the next 10 years.

The production of new seed parents will also receive continuing emphasis, this being a support function in terms of providing other breeders with the means of discovering new hybrid combinations. The first new seed parent was released in 1982, and others are likely each year.

In India the national coordinated program of research in pearl millet is strong, particularly in developing hybrids. We will complement the work of this program by supplying techniques and breeding materials and sharing knowledge. We will maintain the population breeding approach so as to develop high-yielding varieties relevant to the national program in India and abroad.

In African millet growing countries increased production will result from a combination of change in farming practice and genetic improvement within the context of rainfall limitations. Though the existing landraces have good stability of yield, they are relatively inefficient in converting growth to grain. New and more efficient plant types are needed in Sahelian Africa and, since experience has shown that exotic germplasm cannot survive the high pest and disease pressure there, breeding must be done *in situ*. This process has started in six countries spanning the region.

The exposure of test materials to the high disease pressures and disease variability in West Africa, particularly for downy mildew, have been useful in identifying resistances that are not location-specific and hence reliable for breeding use both in Africa and India.

The total ICRISAT program is designed to provide the technology necessary for national scientists to substantially improve millet grain production. This includes socioeconomic information and an understanding of the physical and biotic constraints to yield and ways to ameliorate them. The Farming Systems Research Program will conduct research on the soil-related constraints and the exploitation of intercropping, while the Pearl Millet Program will work on combining genetic resistance to stress with increased grain yield potential.

In addition to our listed objectives, which are applicable to all zones, further research priorities are needed in Africa to:

- Determine effective adaptation zones, the type of cultivar suited to each zone, and locate the most effective breeding and testing sites. We hope this will be done by 1985.
- Determine the effects of interaction of photoperiod response, planting time, and life cycle duration on yield potential, moisture stress, effects, and avoidance of head pests and diseases.
- Begin a small amount of exploratory work on hybrids; screen for resistance to *Striga* and incorporate resistance into new genotypes; a d

identify, in collaboration with the Farming Systems scientists, varieties suited to improved intercropping patterns.

Funding Implications

If funds increase, work would be commenced in Zone II and intensified in Zone I, particularly on adaptation and crop establishment factors and utilization of nitrogen fixation. We would also investigate the possibility of acquiring for grain production in pearl millet the following exceptional traits available in Napier grass (*P. purpureum*): high growth rate, high nitrogen fixation, disease immunities and resistances.

In the event of a decline in availability of funds we would effect economies by adjusting the volume of material, labor, and program travel. If funds decline further some breeding and microbiology projects would be shelved in Zone III. In considering possible reduction of effort on physiological and pathological problems it should be noted that pearl millet does not benefit from research in developed countries to the same extent as other major cereals.

Linkages with Other Institutions

Excellent cooperation has already been established with national programs in India and the Sahelian countries. Links with other institutions will be strengthened and increased as appropriate to achieving program objectives. These already exist with USDA at Tifton, Georgia, and Kansas State University in the USA and with Reading University, the Plant Breeding Institute at Cambridge, and University of Nottingham, UK, on various aspects of plant breeding, agronomy, and physiology.

The protoplast regeneration work on pearl millet currently being explored at the University of Florida and Colorado State University has possible practical applications. Collaboration on nitrogen fixation research exists with the University of Marburg, West Germany, Rothamsted, UK; and the University of Florida, USA. Several areas of collaboration are expected with US Land Grant universities in the Title XII INTSORMIL project.

Pulses

Chickpea (*Cicer arietinum* L.) and pigeonpea (*Cajanus cajan* L. Millsp.) are the principal pulses of subsistence farming systems of the Indian subcontinent and important components of similar systems in other regions of the semi-arid tropics. More than 80% of chickpea and 90% of pigeonpea are produced in the Indian subcontinent. The yields of both these crops are low, and they continue to be grown on marginal soils with low or no input. However, in recent years interest in their cultivation has increased in nontraditional areas and with moderate inputs.

Research in both these crops started almost from scratch and, except for India where a coordinated, well-supported program of research on pulses existed, there was little significant research effort. But even in the Indian program both these crops were part of an overall research effort on a large

number of pulse crops; thus specific attention to chickpea and pigeonpea was limited. The ICRISAT program had to give highest priority to collection and evaluation of germplasm resources and development of strategy for crop improvement.

Chickpea scientists have developed techniques for screening against important diseases such as wilt, *Ascochyta* blight, and stunt, identified lines resistant to these diseases, and distributed them to the national breeders for use in their breeding programs. Lines tolerant to *Heliothis* have been selected. Sources of disease and pest resistance are being incorporated into elite backgrounds. The breeders have made crosses between tall and dwarf and kabuli and desi chickpeas in the search for higher yield potential. Efforts are being made now to incorporate disease and pest resistance. We continue to emphasize the study of methodologies for breeding, identification of chickpea rhizobial strains, and development of suitable agronomic practices for increasing production.

In recognition of the importance of the kabuli type chickpea for the Mediterranean region, we have started a cooperative research program with ICARDA for kabuli improvement of that type. The program is very useful for screening for *Ascochyta* blight resistance. It has been established that winter planting increases production significantly over the present systems of planting in spring provided *Ascochyta* blight-resistant varieties are used. Techniques of screening for *Ascochyta* blight resistance have been developed and resistant sources identified for use in the Mediterranean area and the Indian subcontinent.

In pigeonpea, our research has resulted in the identification of extra-early maturing lines that are useful for many nonconventional areas in northern India in rotation with wheat, and in Australia for mechanized cultivation under rainfed situations.

Selection and development of vegetable pigeonpea, which is in demand in the Caribbean, East Africa, and parts of India has resulted in the production of promising material for use in these areas. Identification of male sterile lines and the possibility of producing hybrids has opened up new avenues for improved yields. Our collaborating scientists have determined that the potential yield of pigeonpea is very high under a rainfed production system with adequate inputs. Identification of lines resistant to wilt, sterility mosaic, and *Phytophthora* blight and less susceptible to *Heliothis* offers potentialities of incorporating some of these traits in elite material to stabilize yields. Our scientists have found that of the three ICRISAT mandate legumes pigeonpea is the only one in which ureide concentration can be used as an index of nitrogen fixation capacity.

Priority Regions

In both chickpea and pigeonpea, overall objectives are the identification or development of genotypes with characteristics which will contribute to higher, more stable yields of acceptable grain type when grown under a range of cropping situations.

In the case of chickpea, the needs are for development of short-duration desi types suited to conditions represented by peninsular India and kabuli types suited to southwest Asia and North Africa; long-duration desi and kabuli types suited to northern India; and desi types for Pakistan, Iran, and Ethiopia. In pigeonpea, the needs are for short-duration grain types responsive to higher inputs and suitable for sole cropping which will fit into rotation with wheat; types adopted to the postrainy season in southern central India; long-duration types for intercropping in central and northern India and eastern Africa; medium-duration types for southern India and West Africa, and for vegetable types adopted to the West Indies, East Africa, and parts of India.

The Pulses Program at ICRISAT has been making an effort to identify priorities vis-a-vis geographical zones in which coordination of research should be recommended. The geographical functional zones for chickpea are indicated in Table 4 and for pigeonpea in Table 5.

In chickpea, we are placing highest priority on the needs of the Indian subcontinent, West Asia, southern Europe, and North Africa, and in pigeonpea

Table 4. Geographical functional zones along with area, production, and yield of chickpea[a].

Priority/Zone	Area (million ha)	Average yield (kg/ha)	Relevant cooperative program
PRIORITY 1			
Zone I			
Indian subcontinent, Afghanistan, and East Africa	9.8	650	National programs in India, Pakistan, Bangladesh, and Ethiopia, breeding mainly for desi types
Zone II			
West Asia, Europe, North Africa	0.56	840	ICRISAT/ICARDA research program for kabuli types
PRIORITY 2			
Zone III			
South America	0.1	1030	National program in Mexico; breeding large-seeded kabuli types for export

[a]Source: FAO, 1978.

Table 5. Geographical functional zones along with area and yield of pigeonpea.

Priority/Zone	Area (million ha)	Average yield (kg/ha)	Relevant cooperative research program
PRIORITY 1			
Zone I			
A. Northern India[a,c] (U.P., M.P., Bihar, and north Indian states)	1.1	960	All India Coordinated Pulse Improvement Project
B. Central and Peninsular India[a,c] (Maharashtra, Karnataka, A.P., Gujarat, Tamil Nadu, Orissa, and other states)	1.5	530	
Zone II			
Kenya, Uganda,[b] Tanzania, Malawi, Mozambique, Southeast Asia, Burma, Thailand, Pakistan	0.3	520	IDRC-supported legume program in Kenya
PRIORITY 2			
Zone III			
Dominican Republic[b], The West Indies, and countries in Central America	0.4	1150[d]	Little organized research on pigeonpea in the region
Zone IV			
West Africa	Figures not available, but area has good potential for pigeonpeas, which are mostly grown as a backyard crop at present.		

Sources: *a*. Directorate of Economics and Statistics, GOI, 1978.
b. FAO, 1975.
c. States with less than 60,000 ha under pigeonpeas are not mentioned individually but are included under others.
d. Figure includes yields of green pods and repeated harvests.

on India and countries in eastern Africa. We will have to depend on special funding for pigeonpea research in East Africa, West Africa, and Central America and for chickpea research in South America (Priority 2).

The Indian subcontinent is the highest priority region for both pigeonpeas and chickpeas. Both crops are important sources of protein in the diet of the people. In India the present production of all pulses is 12 million tonnes, but the requirement to meet dietary needs is 17 million tonnes. Thus there is already a deficit of over 30%. ICRISAT will do everything possible to assist the countries in the Indian subcontinent to increase pulse production in the 1980s.

Available statistics and our own surveys in eastern and parts of southern Africa have revealed the importance of pigeonpeas in that region. Large areas of pigeonpea probably do not figure in the statistics because it is grown as a backyard crop by a large number of poor people. The yield of pigeonpea per hectare is lower than in India, and we feel we must serve that area on a high priority basis.

Many countries in western Africa are very suitable for growing pigeonpeas. If funds become available we will address ourselves to the needs of that region and of Central America.

Research Priorities, Strategies, and Goals

Our high priority research targets for the next decade are:

1. *Environmental stresses*

   - Develop screening techniques for stresses such as moisture, salinity, high temperature, and frost in chickpea, and moisture, waterlogging, and salinity in pigeonpea. We hope that in the next 3 to 5 years these objectives will be achieved.
   - Study factors influencing growth, developments, and phenology in different environments to characterize environments and understand physiological bases of adaptation and stability of yield. These studies will be in collaboration with institutions such as the University of Reading, UK, University of Queensland, Australia, and DSIR, New Zealand.
   - Identification of chickpea and pigeonpea genotypes adapted to nontraditional systems and analysis to determine the major factors limiting yields on farms compared with research stations (yield-gap analysis).

2. *Disease stress management*

   - Develop elite disease-resistant materials.
   - Screen germplasm for additional sources of resistance to wilt, root rots, stunt, *Botrytis* grey mold, and *Ascochyta* blight in chickpea; to wilt, *Phytophthora* blight, and sterility mosaic in pigeonpea; and distribute sources of resistant material through international nursery programs.
   - Study the influence of cropping systems on the incidence of soilborne diseases.
   - Develop projects on emerging disease problems such as *Alternaria* blight on postrainy-season pigeonpeas.
   - Investigate epidemiology of chickpea and pigeonpea diseases and survey potential disease problems.

3. *Pest stress management*

- Screen germplasm and breeding material for resistance to *Heliothis*.
- Intensify research on ecology of important pests, including the study of potential pest problems and pest management practices.
- Develop a package of practices for pest management, the target species being *Heliothis* for chickpeas and *Heliothis* and podfly for pigeonpea.

4. *Nitrogen fixation*

- Study quantity and quality of *Rhizobium* strains in farmers' fields and their relationship to inoculation requirements; develop methods of study of *Rhizobium* strains and legume hosts for improving nitrogen-fixing ability.
- Assess the contribution chickpea and pigeonpea make to the nitrogen nutrition of associated crops in intercropping and sequential crop rotation.
- Develop methods for production and utilization of inoculants.

5. *Breeding for higher yield, stability, and resistances to disease stress*

a. Chickpea

- Improve potential and stability (resistance to diseases, pests, and physiological stresses) of yield of short-duration desi and long-duration desi and kabuli genotypes suited to peninsular and northern India.
- Improve yield potential and stability of kabuli types for West Asia.
- Develop medium-tall chickpea plants with high yield potential.
- Distribute internationally to national programs segregating and pure lines.
- Assess effectiveness of breeding methods and study male sterility to explore production of hybrids.
- Conduct inheritance studies to evolve more effective breeding strategies.

b. Pigeonpea

- Improve the potential and stability of yield for long-, medium-, and short-season pigeonpea suited to intercropping and sole cropping systems in semi-arid tropical areas of the Indian subcontinent, Southeast asia, and East Africa.
- Develop hybrids and exploit heterosis for a range of environments.
- Develop dwarf pigeonpea with high-yield potential under better management conditions.
- Incorporate resistance to the major diseases and pests, tolerance to salinity and waterlogging, and increased ability to fix nitrogen.

Funding Implications

If resources increase we will strengthen cooperative research with ICARDA in the North Africa-Mediterranean region and South America while continuing to emphasize that presently going on in India, Pakistan, Bangladesh and West Asian countries. The program will expand its pigeonpea research to include eastern and southern Africa, the Caribbean islands and Central America, and other areas where demand for this crop is high.

If the available funding has to be reduced further, then we will prune our activities—probably across all subprograms—without affecting teamwork—and redefine our priorities.

Linkages with Other Institutions.

India has a well-organized national pulses improvement project, and pigeonpea and chickpea are two of the several crops in the project. In order to strengthen the already existing cooperation between ICRISAT and the Indian Council of Agricultural Research (ICAR), we propose to study the feasibility of integrating our pigeonpea breeding work with that of ICAR. This will further strengthen our capability to serve the program of the host country as well as those of nontraditional areas.

We already have effective links with ICARDA, the University of Reading (chickpea physiology), Rothamsted (microbiology), Max-Planck Institute (entomology), University of Queensland (pigeonpea cytogenetics). We will strengthen these links and develop others as and when the need arises.

Groundnut

Seventy percent of the world's production of groundnut (*Arachis hypogaea* L.) comes from the developing countries, many of which lie in the semi-arid tropics. The yields of groundnut in the SAT are low, around 800 kg/ha, and the fluctuations in yields are very high. Yields can be substantially increased by management of yield reducers of which the most important are pests, diseases, and the unreliable rainfall patterns of the SAT.

The Groundnut Program at ICRISAT started mid-1976 but significant research only commenced in 1977 with the appointment of staff in some of the disciplines. Physiological and entomological research will become increasingly important in the next decade as full staffing of these subprograms is yet to be completed. The main achievements of the program in the last few years are:

- Initiation of large-scale hybridization programs and improving the success rate in crossing from less than 15% to 60% in the field and in excess of 70% in the glasshouse/screenhouse.
- Development of field and laboratory techniques to screen for rust resistance; identification of new sources of rust resistance which are being used in large-scale hybridization programs with a wide range of commercially acceptable, but rust-succeptible parents.
- Establishment of laboratory facilities and techniques for screening

groundnuts for seed resistance to *Aspergillus flavus* and commencement of large-scale screening.

- Identification and characterization of several groundnut virus diseases. Bud necrosis has been shown to be caused by Tomato Spotted Wilt Virus (TSWV) and transmitted by thrips. Cultural methods of control such as modifying the date of sowing and adjusting plant populations are being developed to control bud necrosis as no sources of resistance have yet been located within groundnut germplasm despite intensive searches. Other important virus diseases identified are Peanut Mottle and 'Clump'.
- Screening of groundnut germplasm for sources of resistance to Peanut Mottle Virus, Clump Virus and other viruses.
- Identification of sources of resistance to thrips and jassids.
- Crossing of leafspot-resistant wild diploid *Arachis* species with the cultivated tetraploid groundnut and restoring fertility to the sterile triploids by treating them with colchicine.
- Initiation of research on the use of tissue and embryo culture to overcome barriers to hybridization which exist between other potentially important species of the genus *Arachis* and the cultivated groundnut.
- Development of high-yielding and early-maturing lines and making them available to the national programs in India and abroad.
- Identification of nonnodulating lines as well as lines with superior nitrogen-fixing ability. The superior lines are being used in breeding programs.

Research Strategies in the 1980s

Priority Regions

India and Africa emerge as the areas of greatest concern when the hectarage, production, consumption, and the contribution the crop makes to the available fat in the human diet are considered (Table 6). In India the compound growth rate of groundnut production for 1961-78 was less than 0.6%; in West Africa it was negative. Thus some groundnut exporting countries have become vegetable oil importing countries. This causes hardship to underprivileged people and a financial strain on national governments.

Southern Africa and Southeast Asia each have a compound growth rate for groundnut production of less than 1%. In eastern Africa the growth rate is 3% but groundnut oil countributes only 8% of the available fat in the diet. The lowest priority area is South America, whose population has a satisfactory fat intake although only a low proportion of this comes from groundnut. ICRISAT considers it can adequately serve South America through the supply of breeding material and advice.

The ICRISAT core research program will continue to focus attention on India and a program will shortly be initiated in Africa. This will start with an IDRC-funded project in Malawi, where a breeder and pathologist will form a team to cover both eastern and southern Africa as part of their regional activities. They will later be core-funded.

Table 6. Geographical and priority groundnut regions, with area, yield and research capabilities.

Functional Region	Area ('000 ha)	Average yield (ha/ha)	Relevant cooperative research program
PRIORITY 1:			
1. India	7200	861	All India Coordinated Oilseeds Research Program exists; National Research Centre for Groundnut (being developed).
2. Western Africa	3051	880	Strong National Programs in Nigeria, Senegambia, others need strengthening. IHRO in francophone countries; GTZ program in Ghana (new).
3. Southern Africa	1156	690	Strong National Programs in Malawi and Zimbabwe; other national programs need strengthening; IDRC oilseeds project in Mozambique (new).
PRIORITY 2:			
1. Eastern Africa	2238	782	Strong National Program in Sudan; others need strengthening; ODA oilseeds project in Tanzania; new IDRC projects in Ethiopia and Tanzania.
2. Southeast Asian countries (excluding India and China	1469	1102	Strong National Program in Thailand; others need strengthening; possibilities of IDRC projects.
3. China	2455	1174	National Program (being developed, potentially strong)
PRIORITY 3:			
1. South America	768	1023	Good National Programs in Argentina and Brazil

Eastern Africa has been given a second priority rating because over 75% of the groundnuts produced in this region come from one country, Sudan, which now has an adequate national research infrastructure because of the high export value of the crop. Sudan, however, should benefit from the supply of breeding material emanating from both ICRISAT Center and the ICRISAT African programs.

Other countries in the eastern African geographical region that wish to increase their groundnut production are Tanzania, Ethiopia, Kenya and Madagascar. They will benefit from the ICRISAT program and regional links will be strengthened by the new IDRC oilseeds projects in Ethiopia and Tanzania, and the British ODA project in Tanzania. The single biggest research capability constraint in this region is the lack of experienced groundnut research scientists and this is where ICRISAT should provide a considerable input through training and advice.

In the southern African region, Malawi and Zimbabwe have adequate research staffing at present but the research programs are not sufficiently funded. Mozambique is desperately trying to increase groundnut production and is receiving help from IDRC, but the program is very small and groundnut research experience is lacking. Zambia also wants to increase groundnut production but lacks facilities and research personnel. Zaire is the largest producing country in the region but no contact has yet been established.

All the countries in eastern and southern Africa grow a range of groundnut types depending on climate (short- or long-season cultivars), end use (confectionery trade, oil extraction, or local consumption) and the farming system (sole crop, intercrop, relay cropping). Malawi, the center for ICRISAT research activities, has a variable range of climatic zones and produces types of cultivars relevant to the region.

A core-funded team of breeder and pathologist similar to that posted in southern Africa is proposed for West Africa and will be started when funds become available. In this region the major producers are Senegambia and Nigeria. Other important producing countries are Cameroon, Niger, and Ghana. Research capabilities in West Africa as a whole have declined but are still strongest in Senegambia and Nigeria, both of which have histories of long and productive research programs. The organization based in Paris, IRHO, has had a strong influence on groundnut research in the francophone countries of the region and is now extending its activities to other countries. The German aid agency, GTZ, has recently funded a crop improvement program in Ghana with groundnut included as one of the crops. ICRISAT has cooperative links with both IRHO and GTZ. The present research capabilities in the region as a whole are deficient in the fields of plant breeding and pathology. If non-core funding becomes available then a microbiologist will be added to both of the ICRISAT African teams.

Other regions listed as second priority areas in Table 6 are "other Asian countries" and China. The Asian nations, excluding India, that are large producers are Burma, Indonesia, Thailand, Viet Nam, Pakistan, and the Philippines. Two other countries, Bangladesh and Malaysia, are interested in

increasing their groundnut production. In this area ICRISAT is already cooperating with most of the countries by supplying breeding material and germplasm. With the present limitation of funds we cannot at present consider setting up core-funded ICRISAT programs in this region. However, UNDP and IDRC have an interest in funding oilseeds projects and we will for the present cooperate with regional bilateral, or national programs.

At present, Thailand has the strongest research capability in the region followed by Pakistan. Research capabilities in Burma, Indonesia and the Philippines are presently not strong. ICRISAT has developed cooperative links with China. Germplasm and breeding lines with resistance to rust have been supplied and training has been given to Chinese scientists, particularly in the fields of cytogenetics, fungal pathology, and virology. Again, we do not anticipate any further input into China by ICRISAT except through supply of genetic materials, techniques, and training.

The more humid areas of this region, including southern China and Indonesia, have problems not found in the other drier regions of the SAT. These problems include bacterial wilt and 'witches broom' disease (the latter probably caused by a mycoplasma), and we are planning collaborative studies on these diseases.

Research Priorities, Strategies and Goals

The high-priority research areas for the next decade are:

Environmental stresses

- Development of methodology within the next 5 years for screening for resistance to moisture stress, temperature stress, nutrient stress, and study of their interrelationships.
- Examination of basic physiological responses to environmental factors to determine if laboratory tests can be used to improve selection procedures.
- Development of large-scale screening programs when the techniques are standardized.

Disease and pest constraints

- Improvement of currently used screening techniques and development of suitable screening techniques for searching for resistance to diseases caused by such fungal pathogens as *Phoma*, *Leptosphaerulina*, and *Fusarium* in Africa.
- Intensification of research on *Aspergillus flavus* and the aflatoxin problem.
- Intensification of research on pod rots and other soil-borne diseases.
- Identification of sources of resistance to important virus diseases and development of control strategies.
- Development of overall disease management strategies combining multiple disease resistance, minimum fungicide use, and cultural control methods.

- Identification of sources of resistance to insect pests, particularly those that are vectors of virus diseases.
- Development of integrated pest control management.
- Development of studies in pest dynamics in various cropping systems and estimation of yield losses due to insect pests.

Nitrogen fixation

- Development of superior inoculants and determination of conditions necessary for their efficient utilization.
- Development of simple *Rhizobium* culture production methods for use by national programs.
- Identification of cultivars with superior nitrogen-fixing capabilities and use of those in breeding programs.

Breeding and cytogenetics

- Development and release to national and regional programs of high-yielding rust-resistant lines, with reasonable levels of resistance to leafspots.
- Development and release of early-maturing, disease-resistant, high-yielding lines for an international testing program in sole crop and for intercropping and relay cropping systems.
- Development of pest- and virus-resistant lines.
- Development of lines adapted to both high and low input conditions.
- Development of tetraploid leafspots-resistant lines from interspecific crosses by 1985 for use by breeders.
- Determination of the potential usefulness of all available wild species for the improvement of the cultivated groundnut.
- Overcoming the crossing barriers that exist between some wild species and the cultivated groundnut by tissue culture and cytogenetic manipulation.
- Investigation of basic cytogenetic problems that may be hindering the progress of breeding programs.

Funding Implications

The Groundnut Improvement Program at present has one subprogram, entomology, still in the developmental stage. The other subprograms are compact and operational with integrated research projects designed to overcome the major constraints that presently limit groundnut production.

If funding becomes limiting then savings could be made by an overall reduction in future research effort and a reduction in the proposed program travel and expenditure on consultants. Reductions in expenditure can also be made on the screening of germplasm for new sources of rust resistance providing there is no change in the present biology of the pathogen. Resistant material so far identified appears to be stable over environments and can be profitably used in breeding programs. Similarly, the present volume of work on

the routine screening of cultivars for resistance to bud necrosis virus can be reduced as it appears that we have no resistance in *A. hypogaea*. Our work will now concentrate on the wild species, which appear to be much more promising sources of resistance, and this will reduce the amount and cost of the work. If, however, funds remain static we foresee no increase in the size of the present research effort. In the event of the availability of extra funds, we will strengthen groundnut research in Southeast Asia, concentrating on the rice-based cropping programs and initiate work on bacterial blight and "witches-broom" disease. Likewise, the strengthening of the African teams by the inclusion of physiologists and microbiologists would be justified.

Linkages

Presently we have strong links with North Carolina State University, USDA (USA); Reading University (UK), and Imperial College (UK) in breeding, cytogenetics and disease resistance and nitrogen fixation studies. We are cooperating with virus research institutes in Japan, UK, USA, West Germany, and Africa, and hope to become involved with virus disease surveys in Africa and East Asia. We are taking part in the International Meloidogyne project organized by North Carolina. We have been involved with the planning phase of the USA Title XII Peanut Program and will be collaborating in several of the proposed research projects.

Genetic Resources

The key to success in crop improvement research lies in the variability and potentiality of the world's genetic resources. The international centers thus are in a unique position, not only to enrich their own programs but also to make invaluable genetic material available to scientists all over the world. To meet this objective, ICRISAT established the Genetic Resources Program in January 1979. We have embarked on a long-range program of collection, evaluation, maintenance, conservation, documentation, utilization and exchange of germplasm of the Institute's five mandate crops and six minor millets[1] as requested by the International Board for Plant Genetic Resources (IBPGR).

Presently there are over 71,600 accessions of germplasm assembled and conserved in the medium-term gene bank of ICRISAT. The number of accessions by crops is given in Table 7.

The collection is considered small compared to the worldwide genetic diversity that is not yet assembled and conserved.

In the next decade, we will intensify our global activities in collection, our regional activities in maintenance, conservation, documentation, and evaluation, and our SAT responsibilities for utilization and distribution. The most important areas of future collection are in Africa, Asia, and South and Central

---

[1] Proso millet (*Panicum miliaceum*), foxtail millet (*Setaria italica*), little millet (*Panicum sumatrense*), barnyard millet (*Echinochloa crus-galli*), and kodo millet (*Paspalum scrobiculatum*).

Table 7. Accessions of germplasm in the medium-term gene bank at ICRISAT as of Feb 1982.

Crop	No. of accessions	Areas fairly well represented	Priority areas to be explored
Sorghum	21,264	Eastern & South Central Africa, India	Western, Northern and Southern Africa, parts of Asia and near East
Pearl Millet	14,340	India, South Central Africa, parts of Eastern Africa	Western, North Eastern, parts of Eastern and Southern Africa, Asia
Pigeonpea	9,697	South Central Asia, Philippines Trinidad, Puerto Rico, Australia, Kenya	Eastern & Western Africa, Caribbean Islands and surrounding countries in the Gulf of Mexico and South America
Chickpea	12,375	India, Iran Afganistan, Turkey, Israel, Spain and Mexico	East Africa, Ethiopia, Egypt, North West Africa, Western Asia, Algeria, Tunisia, USSR, Portugal, Argentina
Groundnut	9,911	India, U.S.A., Senegambia	Brazil, Peru, Argentina, Ecuador, Bolivia and other South American & Caribbean countries, Burma, Indonesia, Eastern and Western Africa, China
Minor millets	4,039	India, Pakistan, East & South Central Africa	Eastern, Northern and South Central Africa, China, USSR and South Central Asia
Total	71,625		

America. A concerted effort will be made to salvage the important vanishing landraces and to capture new and desirable genetic traits, including those in wild species, for use in present and future crop improvement programs. Survey of cytogenetic variation, population studies, introgression and conversion, morphogenetic and taxonomic monographs will form part of ongoing activities.

The specialized collection and evaluation program, as well as the refinement of the applied research activities, will continue. The behavior and viability of seeds under medium- and long-term storage conditions will be studied. A special attempt will be made to form morphological and geographical gene pools which will aid in future germplasm conservation and utilization in SAT.

ICRISAT will cooperate with national and international organizations to establish regional germplasm conservation and evaluation centers in West and eastern Africa. The new Sahelian center of ICRISAT could serve as a suitable center for the development and operation of the regional genetic resources program for millets and groundnut in West Africa. At least one crop-specific genetic resources staff could be stationed there for 1 or 2 years to be followed by other crop-specific staff on rotational basis. Such an arrangement will assure more thorough germplasm collection, evaluation, utilization, and conservation in the region.

Funding Implications

Financial constraints may limit some of the major efforts in collection and related aspects of the Genetic Resources Program. With improved funding possibilities, we would establish a small regional center in East Africa in collaboration with national programs, possibly near or at a future ICRISAT regional center. The genetic resources regional activity would emphasize concerted germplasm collection and their evaluation at or near their natural habitat. Much importance is placed on this effort in view of the present drawback in attempting to evaluate all germplasm at Patancheru, away from its area of collection and natural habitat. The implication of this problem is so great that certain superior landraces may not be utilized properly because of their being evaluated in an area where they are not adapted.

The regional center would require limited transportation facilities for collection missions, land for evaluation, and laboratory for handling and conserving the germplasm.

Declining resources would prevent a major effort in collection, evaluation, and utilization research on minor millets but we would at least continue a holding operation and exchange facility. If we are compelled to reduce our collection effort because of declining funds, it will be a great setback to the program of ICRISAT.

3.3 Resource Management Research

Farming Systems

Research to improve resource management commenced at ICRISAT Center at Patancheru, India in 1972. The site possesses two representative benchmark soils, Alfisols and Vertisols, in an agroclimate representative of the SAT. While recognizing the location specificity in farming systems research, it was considered that the work at the Center would provide the basis for development of technology for the underutilized black soils (Vertisols) and increasing agroclimatic situations

It was decided that initially the main thrusts should center around development of technology for the underutilized back soils (Vertisols) and increasing our understanding of the other important group of soils (Alfisols). Interdisciplinary research has made considerable progress in understanding the problems of these soils and in working out solutions on an operational scale in a few

well-defined environments in SAT India. Some of the important achievements are:

- The climatological data of several semi-arid tropical locations in India and West Africa have been analyzed and concepts for utilization of different agroclimatic regions have been developed. Analyses of the probabilities of rainfall coupled with soils information enabled the delineation of the areas for likely success of rainy-season cropping.
- It was established that crop production in the semi-arid tropics is not only limited by low and unreliable rainfall but also by poor soil fertility. The application of fertilizer is essential.
- Modeling techniques were used to predict the performance of sorghum under different moisture environments, to estimate the runoff and drainage components of the water balance, and to predict the quantity and distribution of water in the soil.
- A concept of watershed-based, broadbed-and-furrow technology of land management was developed to conserve soil and water and to facilitate cropping of the deep Vertisols during the rainy season. It facilitates harvesting of excess runoff water for supplemental irrigation. Collaborative research with the All India Coordinated Research Project for Dryland Agriculture (AICRPDA) has been undertaken to evaluate this technology under different environments.
- Improved cropping systems also have been developed on the deep Vertisols to utilize the rainy season period when they have been traditionally left fallow. In assured rainfall areas, rainy-season cereal crops have been grown without reducing the yields of post-rainy-season crops; a cereal intercropped with a long duration pigeonpea has been particularly promising and has given much more stable returns than sole crop systems.
- Intercropping has been shown to be a very efficient way of increasing crop productivity. Cereal/pigeonpea intercropping has given full yields of cereal and a "bonus" of 50 to 90% pigeonpea yield depending on the residual soil moisture supply. Pearl millet/groundnut intercropping has consistently given yield advantages of 25 to 30% on Alfisols, with even greater benefits under conditions of moisture and nutrient stress.
- The development of multipurpose animal-drawn wheeled tool carriers was given emphasis in the initial years. The Tropicultor with various attachments has proved to be a promising machine.

Research Strategies

Farming systems research includes four broad areas: base-line studies, component research, experiment station research, and on-farm research (TAC Stripe Review of Farming Systems, 1978). The factor-based component research and the watershed-based integrated research at ICRISAT Center received the greatest attention in the 1970s from the Farming Systems Research Program. Base-line studies were emphasized in the Economics Program. In the 1980s greater emphasis is being given to on-farm

research, although in Africa considerable center-based research is still necessary. The proportionate allocation of time and resources to base data analysis, on-center research, and on-farm research will depend on the stage of development of such research and the semi-arid tropical region in which it is being conducted. The individual disciplines will devote much effort to integrated research while maintaining appropriate emphasis on factor-oriented research.

Development of research methodology will remain an important activity. One of the strategies in farming systems research at ICRISAT will be to incorporate a problem-oriented approach involving multidisciplinary teams drawn from all programs to focus on well-defined subject matter areas of high priority in the attainment of ICRISAT's objectives. During the 1980s particular emphasis will be directed to conducting farming systems research in collaboration with national and regional institutions responsible for both training and extension.

It is recognized that on-farm research plays a key role in providing information to shape priorities. ICRISAT will endeavor to have a strong program of on-farm research in which national programs are involved, particularly at the stage of on-farm testing of prospective technologies.

Widely different management systems will be required for the diverse SAT soils. Four major soil orders—Alfisols, Entisols, Oxisols, and Vertisols—encompass approximately 85% of the SAT. Alfisols and Entisols predominate in West Africa, and Alfisols and Vertisols in Asia; thus our research will concentrate on these soils. The Farming Systems Program will collaborate with other agencies and national programs on research in other regions to evolve improved farming systems.

Research Priority Areas

Characterization of resources and identification of benchmark sites

Compilation of information on the agroclimatic and soil resources of the SAT will receive high priority in the selection of representative benchmark sites for developing and evaluating new technologies for a wide range of environments encompassing the major soil orders of the SAT. Agroclimatic surveys will be continued for the next 4 to 5 years to permit evaluation of the needs for farming systems research. Soil maps of various levels of accuracy exist, but there is a need to coordinate and summarize existing data with planned agroclimatic work.

Double cropping of Vertisols and refinement of technology for shallow and medium Vertisols

For deep Vertisols, the major objective will be on-farm studies to evaluate and modify the technology that was developed in the 1970s at ICRISAT Center. For shallow and medium-deep black soils, the technology will be further refined. We hope by 1985 to have appropriate technology for evaluation in on-farm studies.

Development of alternative land and water management techniques for Alfisols and Entisols

In research on Alfisols, the aim is to study alternative land configurations and management techniques for increasing infiltration, minimizing erosion, and enhancing the potential for life-saving irrigation. A substantial research effort will be made for development of land-and-water-management systems for the light-textured Entisols and Alfisols of West Africa with particularly low water-holding capacity, susceptibility to leaching, and consequently greater likelihood of moisture and nutrient stress. The research areas in eastern and southern Africa will be taken up as resources become available.

Rainwater management

Rainwater management and use will receive more critical evaluation in on-farm as well on-station researches. We will continue to seek better methods for runoff water management in typical soils of the SAT.

In operational-scale experiments yield increases of the order of two to three times that of the traditional technology have been demonstrated from systems involving use of improved variety, fertilizer, soil and crop management, and supplemental life-saving irrigation.

On-farm research for evaluation and transfer of technology in three villages has shown that the new technology increased farmers' production severalfold. These involved Alfisols receiving low rainfall, deep Vertisols receiving low rainfall, and medium-deep Vertisols receiving medium rainfall.

Cropping for diverse environments

Our cropping systems research will emphasize the development of systems that make more efficient use of limited resources, especially moisture and nutrients. The soil physicists, climatologists, and soil and water management engineers will concentrate on studies relating crop production to varying moisture environment and range of inputs. By 1985 the major research effort will be on building up conceptual cropping models for the soil groups other than deep Vertisols in the SAT.

Machinery and tool development

We will emphasize improving the efficiency of farm inputs and operations as effected by the use of the machinery appropriate to the farmers conditions and resources. Development and refinement of simple and reliable equipment to accomplish these will be carried out.

Nutrient management for improved productivity

Special attention will be given to improving nutrient efficiency in different cropping systems involving ICRISAT crops. In the first 5 years, major emphasis will be on studies of nitrogen. Improving the efficiency of nitrogenous fertilizer will be studied by soil scientists, soil physicists, and agronomists.

Nitrogen losses and development of techniques for reducing these under a range of soil and moisture conditions will receive more attention initially. Long-term studies of residue management, biological nitrogen fixation, and green manuring will be conducted. Other nutrients such as phosphorus, zinc, sulfur, and potassium will receive greater attention at a later stage.

Weed, pest, and disease management

New and improved cropping systems frequently generate new weed, pest, and disease problems. In collaborative studies with scientists in the crop improvement programs, increased attention will be given to the development of systems that allow satisfactory integrated management.

Funding Implications

The plan presented in the preceding pages is based on the assumption that the flow of funds shall remain constant in real terms over the next few years. If funding improves, we plan to expand our geographical coverage and collaborative work with national programs. If funds decline we will reduce our input on deep Vertisols at ICRISAT Center. The designing and development of wheeled tool carriers will receive decreased emphasis. The machines already designed and developed will be tested in the on-farm phase. Basic research in soil fertility and chemistry will be done in collaboration with centers of excellence in mentor institutes. The mapping work for the delineation of semi-arid tropical areas will receive less attention.

Linkages with Other Institutions

Farming Systems research must be an integrated effort both within the Institute and outside it. Linkages with other institutes, universities, and development organizations in India and elsewhere are essential to provide theoretical back-up of the research findings, the testing of technology developed, and its transfer.

Linkages have been established with 16 experimental stations of the Indian Council of Agricultural Research (ICAR) for further development and testing of research results from ICRISAT. Similarly, in Upper Volta and Niger, all farming systems work is conducted in close collaboration with the national institutions so that the research findings can be transferred quickly.

International linkages are also being developed with Texas A & M University, USA, for sorghum modeling; ORSTOM, France, for study of climatology of West Africa; Nottingham University, UK, for modeling of water and crop growth; Weed Research Organization, UK, for weed research; Tillage Laboratory, State Agricultural University, Netherlands, for tillage work in West Africa; International Fertilizer Development Center, USA, for nitrogen studies; National Institute of Agricultural Engineering, UK, for development of low-cost tool carriers.

Economics

Economics research has focused attention on problems of technology and of economic and institutional policy. First priority has been given to identification of constraints, evaluation of options, and making recommendations to overcome these constraints.

In the last 7 years, the program has developed a number of methodologies that are being utilized by other economists in the SAT and elsewhere. These include methodologies to:

- Conduct multidisciplinary village studies to understand constraints to food production and development and to evaluate prospective technologies.
- Determine and measure the extent and importance of agricultural risk and risk attitudes.
- Study issues of efficiency and equity in research resources allocation including questions relating to human and nutritional priorities and technology suited to small and large farmers.
- Conduct economic analysis of on-station and on-farm experiments.
- Derive consumer preference indices for SAT food grains—particularly sorghum—using their cryptic and evident characteristics.
- Evaluate social, organizational, and institutional requirements for successful adoption of new technologies and improvement of productivity of resources.

Research Strategy

In formulating research programs and giving them appropriate priority in the next 10 years we will keep the following five points in view:

1. Based on the experience of the 1970s, we feel that there is a general lack of suitable technologies especially designed to improve productivity of SAT agriculture; and we have to continually search for such technologies.
2. We must strengthen our efforts to identify and evaluate institutional policy options that would improve access to technology, particularly for small farmers of limited means.
3. Institutional issues that determine the availability of limited environmental resources having common property characteristics such as runoff and groundwater, pastures and forests, should receive increased attention.
4. Regarding the geographical direction of our research, we will maintain our present level of research in the Asian SAT throughout the 1980s, intensify our research relevant to West Africa in the next 5 years, and extend such efforts to East Africa.
5. The number of our core staff is anticipated to remain unchanged, so further work will be carried out within the capacity of present strength and within given budget constraints. Suitable collaborative arrangements with other institutions for specific research projects will be given appropriate priority.

Research Priorities

The major research priorities, assuming normal growth of funds, are depicted in Table 8. A brief outline is given below:

Analysis of traditional farming systems

In addition to the three southern Indian villages under intensive study since 1975, there will be four new villages under study in groundnut, chickpea, and pearl millet growing areas of Gujarat and Madhya Pradesh in central and northern India. Similarly in West Africa, sites in Upper Volta and Niger are being selected for intensive studies. All of these studies will continue until 1985.

Assessment of prospective technologies

This will continue throughout the decade in both India and West Africa in collaboration with national programs. Modeling and simulation will form an increasing component of such studies.

Environmental use and social organization

Studies of the use of common property resources will be initiated from 1981. Conclusions from Indian studies on social organization, particularly those related to watershed development, will be further evaluated.

Studies of traditional tanks

Policy implications from studies conducted in India will be brought to the attention of policy makers, and investigations into the possibility of tank irrigation in West Africa will be initiated.

Mechanization studies

Studies on animal drawn implements and tractors in West Africa will be initiated. Differences in man/land ratios and wage/price relationships may imply different conclusions than those arrived at for the Indian and South Asian situation. It is expected that these studies will be completed by 1985. Problems of availability of alternative energy sources for SAT agriculture will also be studied.

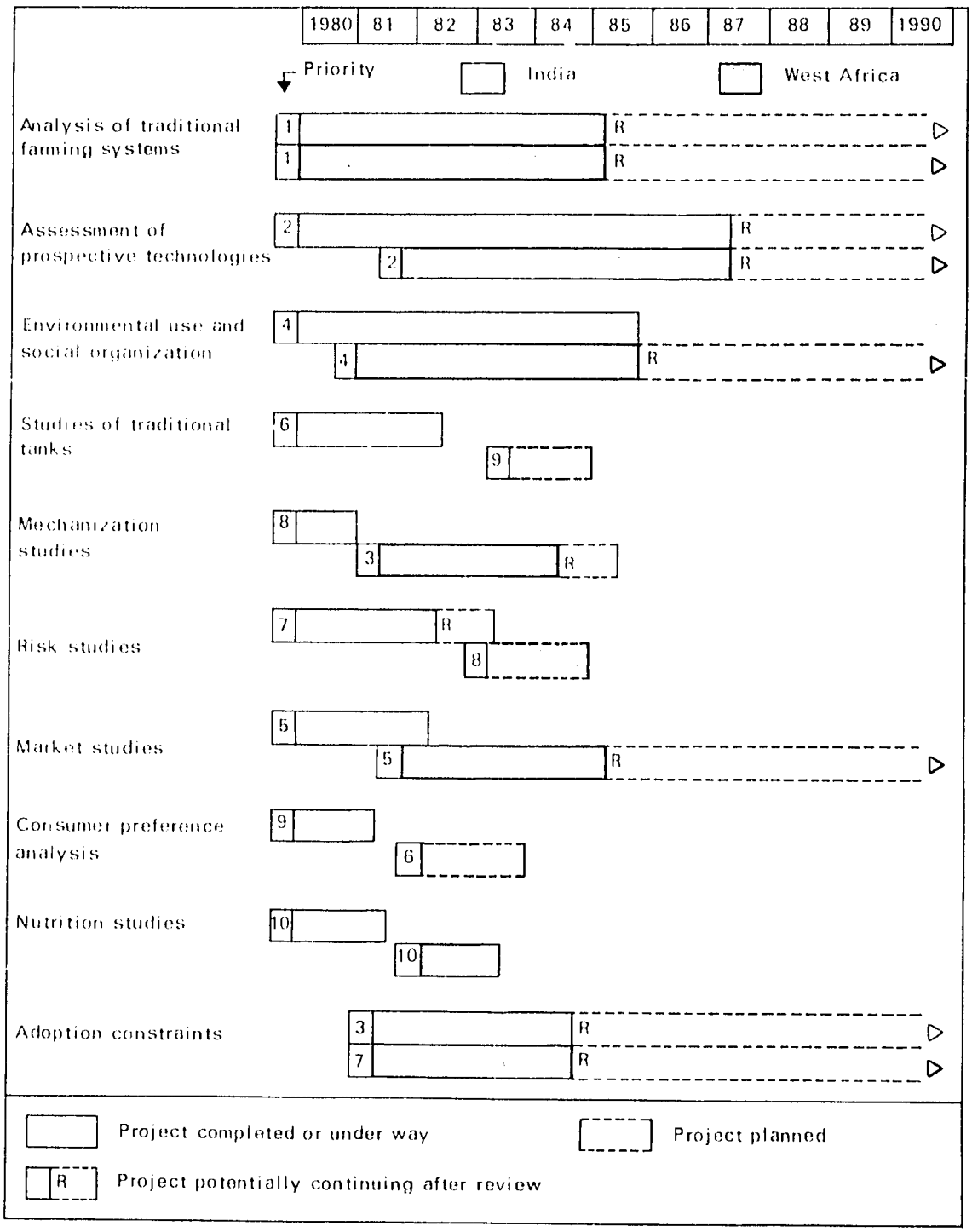
Risk studies

Studies on the nature and extent of risks and SAT farmers' perceptions of risks will be conducted in India and West Africa in the early 1980s. Results from both regions will be compared and policy implications derived by 1985.

Market studies

The past and present work on supply and demand elasticities of sorghum, pearl millet, groundnut, and pulses will be utilized to carry out analyses simulat-

Table 8. Present and future socioeconomic research projects in India and West Africa (Upper Volta and Niger).



ing the effects that various technology and policy scenarios could have on prices, production, resource use, and human welfare. These studies will be updated in 1985 and again in 1990 to derive implications for ICRISAT's research strategies.

Consumer preference analysis

Studies on consumer preference in sorghum and pearl millet will be extended to West Africa and the implications for research strategies brought to the attention of breeders. This study should be completed by 1985.

Adoption studies and constraint analysis

Studies of the adoption of improved technologies and their effects will commence in 1981 in India and West Africa. To understand the gaps between the performance of new technologies on research stations, in on-farm experiments, and in farmers' fields, studies will be undertaken in collaboration with national programs and policy implications drawn.

Collaboration and Training

Collaborative research has always been a significant part of our strategy. For example, we recently completed a study with the Indian Agricultural Statistics Research Institute on fertilizer use on sorghum and millets. Research on adaptability, stability, and risk in sorghum breeding was undertaken with the All India Coordinated Sorghum Improvement Project (AICSIP). Gujarat Agricultural University and Jawaharlal Nehru Krishi Vishwa Vidyalaya in Madhya Pradesh are collaborating in our village studies in those states. Professor T.D. Wallace of the Department of Economics at Duke University, USA, is collaborating with us in a study of rural labor supply response and technological change. We are negotiating with the International Food Policy Research Institute (IFPRI) for cooperative research in India and West Africa on demand, supply, and marketing policies for sorghum and millets.

Collaboration with national, regional, and international organizations in conducting studies of mutual interest and of relevance to the SAT will receive greater attention in the 1980s.

Training of economists from national programs for collaborative studies will be given a high priority.

Funding Implications

The above priorities assume a normal growth rate of program funds. If funds remain constant, priorities 10 and 9 in Table 8 probably will be dropped in both India and West Africa. If funds decrease then projects will be deleted in descending order of priority, commencing with 8. The precise curtailment would depend on the size of the reduction in funds.

4. Transfer of Information and Technology

The fourth objective of ICRISAT is to assist in the development and transfer of technology through cooperation with national and regional research programs by sponsoring conferences, operating international training programs, and assisting extension activities. Clearly this implies a commitment to applying the product of ICRISAT's research programs—both knowledge and technology that is fully proven—to regions of the SAT where it is relevant. The Governing Board of ICRISAT accepted this challenge by setting up a Technology Transfer Committee whose specific aims are to facilitate and assist this effort. The committee is empowered to:

1. Decide what products of ICRISAT research programs are ready for transfer to national agricultural action programs. These products range from new methodology and crop breeding lines and cultivars to more complex technology from Farming Systems Programs (packages of technology and follow-up action from studies in villages).

2. Plan and advise on action programs to transfer technology, ensuring feedback from such programs to research workers to indicate the need for further research.

Although ICRISAT is relatively young, transfer of technology has already begun and certain channels have been established both in India and in African countries. They can be broadly categorized as follows.

a. Scientist to scientist interaction. Very real contributions are being made to national and regional programs by exchanges of ideas, early-generation plant breeding lines and technology, particularly in the area of screening for stress. This will grow in the next 10 years. The process is facilitated in Africa by the fact that ICRISAT scientists work at national research stations and attend national research meetings on crops in ICRISAT's mandate.

b. Seed materials from germplasm collections and from ICRISAT breeding programs, and in some instances tested materials from other national breeding programs in Asia and Africa, are made readily available through ICRISAT's network. As far as possible, this is done through national testing programs and seed multiplication or variety release schemes. ICRISAT is able to readily mobilize and distribute materials in mandate crops.

c. Application of improved technology or technological practices in consultation with national agencies and universities in pre-extension projects. This technique will be increasingly used in the future, building on the data base accumulated from our village level studies in India and now beginning in Upper Volta and Niger and from our experience gained from introduction of the improved technology for utilization of double cropping systems on the deep Vertisols in India. ICRISAT will not become involved in direct extension work

but, correctly, should become involved in identifying constraints and problems associated with the transfer of research results from the closely supervised research station situation to the farmers' fields and the evaluation of constraints at that level.

d. ICRISAT has a role to play in informing policy makers and senior government officials of advances in research methodology and potential payoffs from research. The exact mechanisms of ensuring such transfer vary. It can be by direct contacts at high levels, visits to ICRISAT Center, and sometimes in more formal sessions on specialized topics.

By virtue of links with developed and developing countries, ICRISAT is increasingly able to host workshops, symposia and conferences, at which the most recent research findings can be made known. These gatherings range from small specialist consultant workshops, such as on crop modeling or yield assessment, to large conferences involving broader representation from developed and developing countries which give a broad input into future planning strategies for a whole area of research.

e. Training assumes special importance, given the expertise and facilities available both at ICRISAT Center and in Cooperative Programs. A range of disciplines are covered and an increasing body of research information is being accumulated with specific relevance to SAT areas. Good progress has been made but constant reviews of strategy are necessary to maximize effectiveness. The capacity to train technical and scientific personnel is limited. More accent will be placed in the future on the training of trainers and an expansion of training in cooperating countries.

4.1 Training

A major constraint to agricultural research and development in SAT countries will continue to be the shortage of skilled manpower to carry forward dynamic programs of crop improvement, farming systems, and production technology. Our training program therefore has a significant responsibility to assist in providing trained agriculturalists who can work more effectively in research, extension, and training activities. One of ICRISAT's major contributions will be through training nationals of SAT countries to develop and plan rational and relevant research programs for their countries. It is vital that strong indigenous research programs be developed to capitalize on research results and material coming forward from ICRISAT programs.

The strategy is to provide educational opportunities and practical experiences for personnel from national programs and donor countries who are working or intend to work in national, regional, or international agricultural research or development programs in the rainfed SAT. These training programs will continue to utilize the Institute's unique access to genetic resources, SAT environments, scientific expertise, research experience with selected tropical crops, access to scientific literature, and scientific equipment and facilities for providing multidisciplinary training opportunities. Trainees are classified as International Interns, Research Fellows, Research Scholars, In-service Fellows, In-service Trainees, and Apprentices.

ICRISAT's training program has been designed to encompass training of all categories needed to support a durable and expanding research base for its mandate crops and SAT farming systems. Trainee categories of International Interns, Research Fellows, Research Scholars and Inservice Fellows are the future research scientists who will actively carry out research in our mandate area. In-service Trainees and Apprentices are junior scientists and research technicians who will support these scientists. During the first 10 years of training at ICRISAT, the greatest need has been for training junior scientists and research technicians. During the next phase, more opportunity will be given to training of all ICRISAT categories of research scientists--from International Interns to In-service Fellows. By attempting to identify and train more scientists, both from developing and developed countries, we will ensure a steady flow of scientific manpower for research on our mandate crops, farming systems and economics to research agencies in the SAT.

The largest number of trainees have participated in sorghum and pearl millet improvement and production training. The interest in specialized training in pathology, entomology, physiology, microbiology, soil physics, soil fertility, socioeconomics, and research management will significantly increase with the increase in the academic qualifications of applicants. Requests for more training in groundnut, chickpea, pigeonpea, and farming systems research areas are expected to continue to increase.

We hope increasingly to assist scientists in the cooperative programs to conduct training programs in crop improvement, crop production, and farming systems. These training activities would be organized in association with national training facilities in the regional areas and would enable training of persons in their regions of work and the language of their scientific activities. Such training would be conducted in English, French, or Spanish. As an adjunct to these programs, the development of autotutorial teaching units in various languages is anticipated. Training in locations away from ICRISAT Center will require more time from individual scientists and added expense for facilities and maintenance of each trainee. However, such programs would potentially increase the number of trainees who cannot be trained in an English-language program or would be unavailable for training outside their home countries.

As more information becomes available from research programs such as useful technology for management of water and soils, short training courses will be mounted to make national program staff in both research and extension aware of the range of options open to farmers for better management of their land. Increasingly research workers from national programs will be brought in for special courses of the type already mounted on pulse entomology in 1981 which seek to concentrate on specific problem areas.

Training opportunities at the Institute are currently limited by space, staff, and facilities and by the level of training requested and accepted. It is anticipated that up to 60 persons can be accommodated each year in 6-month inservice training and up to 30 scientists and students in 1-year or 2-year programs. Short, specific training programs will be mounted as and when desirable and will accommodate from six to about 30 persons.

It is estimated that 40 to 60% of the in-service training will be financed by national and development projects, while the student scholarships, research fellowships, and international internships will be more dependent on Institute funds. A reduction in training funds would require us to reduce the more costly high-level training—international internships, research fellowships, and scholarships away from ICRISAT Center—and opportunity for in-service training and possibly curtail the number of all applicants accepted for sponsorship by ICRISAT at all levels of training.

4.2 Workshops, Seminars, and Conferences

Since its inception, ICRISAT has sponsored and cosponsored a wide range of workshops, seminars, and conferences. These have been of several types and all have contributed significantly to dissemination of existing research information and to planning of ICRISAT's programs of assistance to international, regional, or national programs of research. Conferences on sorghum and millet in 1977 and groundnut and pigeonpea in 1980 contributed significantly to formulating ICRISAT's strategy for crop improvement programs and, at the same time, enabled vital cross program links to be forged with national programs and research scientists throughout the SAT and in developed countries. Detailed workshops of the type held in 1975 on ergot and downy mildew of pearl millet and in 1979 on soilborne diseases of chickpea, identified priority problems with these diseases.

One of the important objectives of the ICRISAT workshop and symposium program is to enable adequate state of the art summaries to be prepared, such as was done in the publications "Socioeconomic Constraints to Development of Semi-Arid Tropical Agriculture" and "Development and Transfer of Technology." Smaller workshops, such as those on agroclimatology, and *Heliothis*, an important pest of many crops, have enabled strategies and techniques to be evaluated by small groups of concerned scientists and resulted in concerted integrated action on assembling data in the SAT.

It is proposed to continue this strategy in the next 10 years using a spectrum of conferences and workshops—some catering to small specific groups and some to much larger groups of research workers, administrators, and policy makers, and representatives of donor agencies. Emphasis always will be placed on ensuring good representation from ICRISAT's main client group, the scientists of the SAT. An important large workshop, Sorghum in the Eighties, was held to examine the results of a similar broad spectrum workshop held in the early 1970s, when a broad strategy was planned. The successes and failures of plans charted at this conference will be used to determine strategies for the 1980's.

Specialized small workshops will be held increasingly within developing countries. A workshop on *Striga* was held in Upper Volta in 1981 and a further workshop is likely to be held on Socioeconomic Constraints to Development in West Africa, in 1983.

4.3 Information and Library Services

Dissemination of information will play an increasingly important role in transferring the technology developed through our research. This function is handled by our Information Services Division and our Library, which not only serves the interest of scientists at ICRISAT Center but also operates a Sorghum and Millets Information Center funded by IDRC that provides information on these two crops to scientists throughout the SAT. Information is relayed to our client groups as it is developed. This takes the form of detailed publications such as information bulletins and research reports, workshop proceedings, specialized newsletters, the technical annual report, and a well-illustrated, non-technical compilation of research highlights published annually for non-scientific audiences. The Library is developing into a center for world literature on major and related subjects of concern to the Institute. Its documentation activity is confined to the five mandate crops, and it hopes to soon extend to scientists of SAT countries the selective dissemination of information (SDI) services it is now providing to ICRISAT scientists on matters of special interest to them.

5. Organization and Cooperation

5.1 Organization at ICRISAT Center

ICRISAT, like most of the other IARCs, is organized mainly by function. The essential organizational units are six multidisciplinary research programs and the training program.Four of the research programs—in sorghum, millets, pulses and groundnuts—are crop improvement programs. The other two—farming systems and economics (more properly socioeconomics)—are mainly involved in resource management research. Each research program is headed by a program leader. Within each research program there are several disciplinary subprograms, each headed by a principal scientist. In addition to six research programs, there are seven research support programs—Genetic Resources, Farm Operations, Biochemistry, Plant Quarantine, Library, Statistics and Computer Services. These research and support programs are all guided and supervised by the Director of Research. (See organizational charts, Figs. 4-6).

The crop improvement programs generally have subprograms on breeding, physiology, pathology, microbiology, and entomology, except for Millet, which has no separate entomology unit. The Groundnut Program has additional subprograms of virology and cytogenetics. The entomology subprogram in Sorghum serves the Millet Program, and the microbiology unit of Millet serves the Sorghum Program. The Farming Systems Program has subprograms on cropping systems, land and water management, farm power and equipment, soil fertility, environmental physics, and agroclimatology. The Farming Systems Program also interacts with Economics and the crop improvement programs.

The research support programs provide common and necessary services to the research programs. The Genetic Resources, Biochemistry and Plant

Figure 4. ICRISAT's Research Organization.

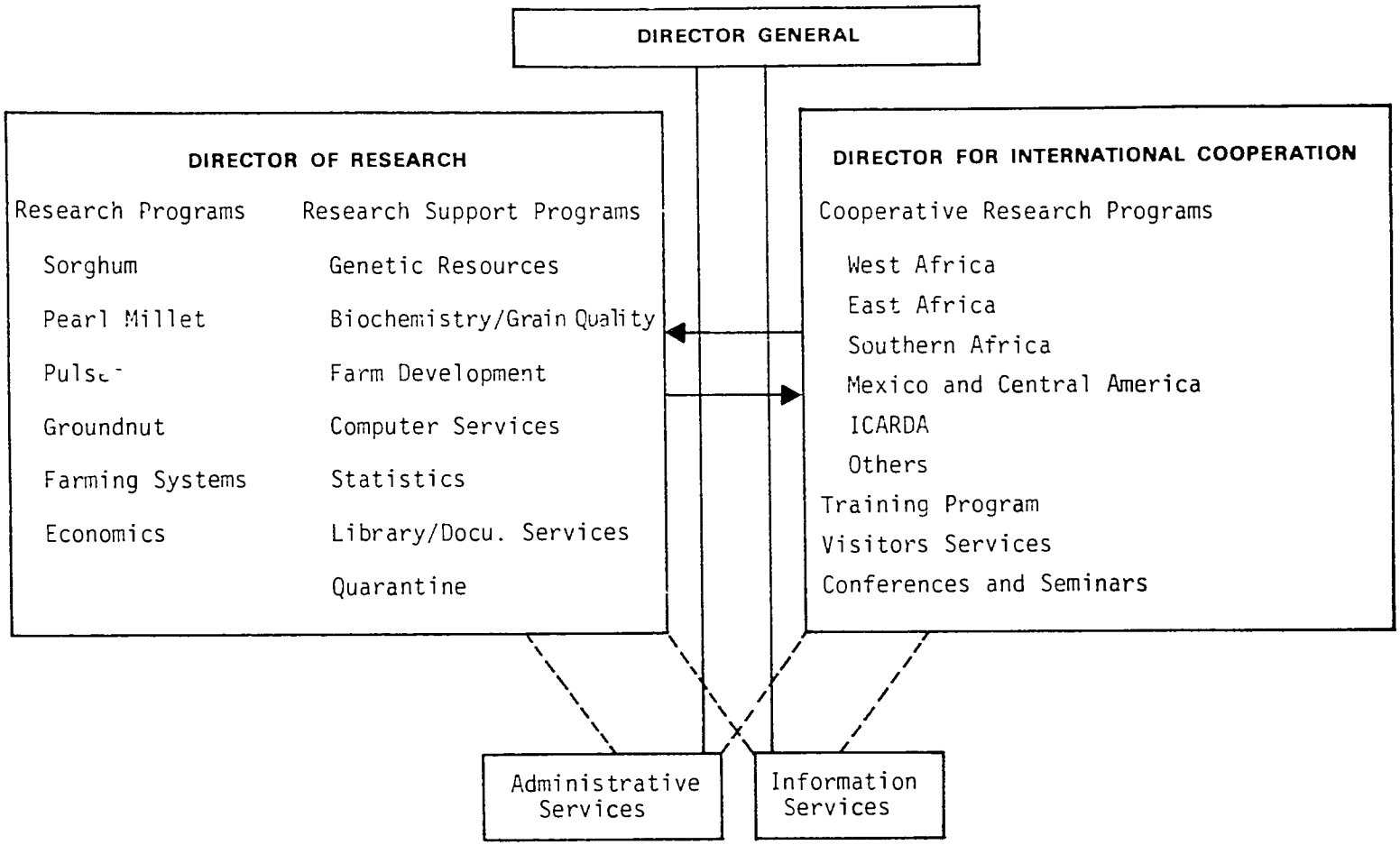


Figure 5. Research organization by programs under Director of Research.

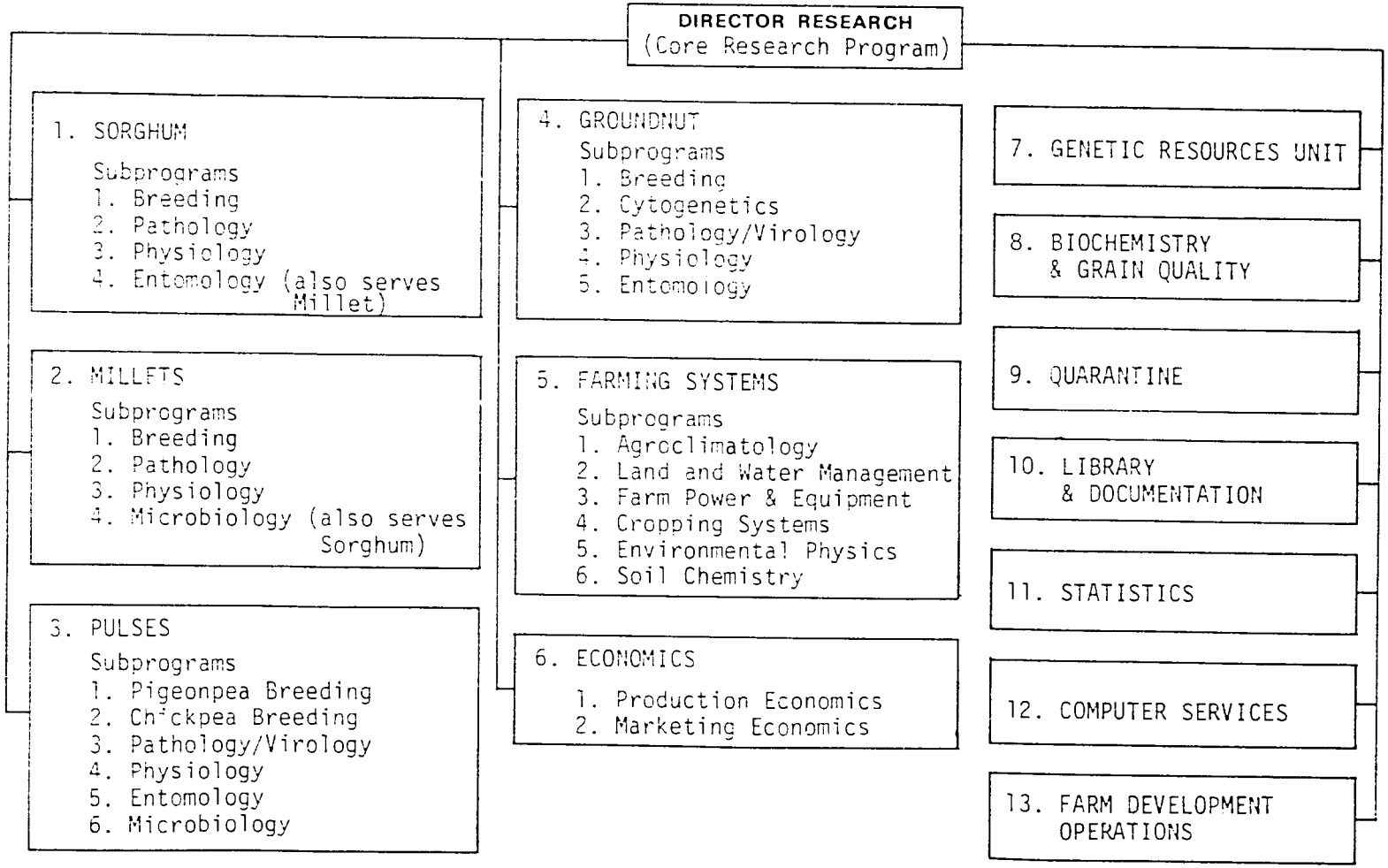
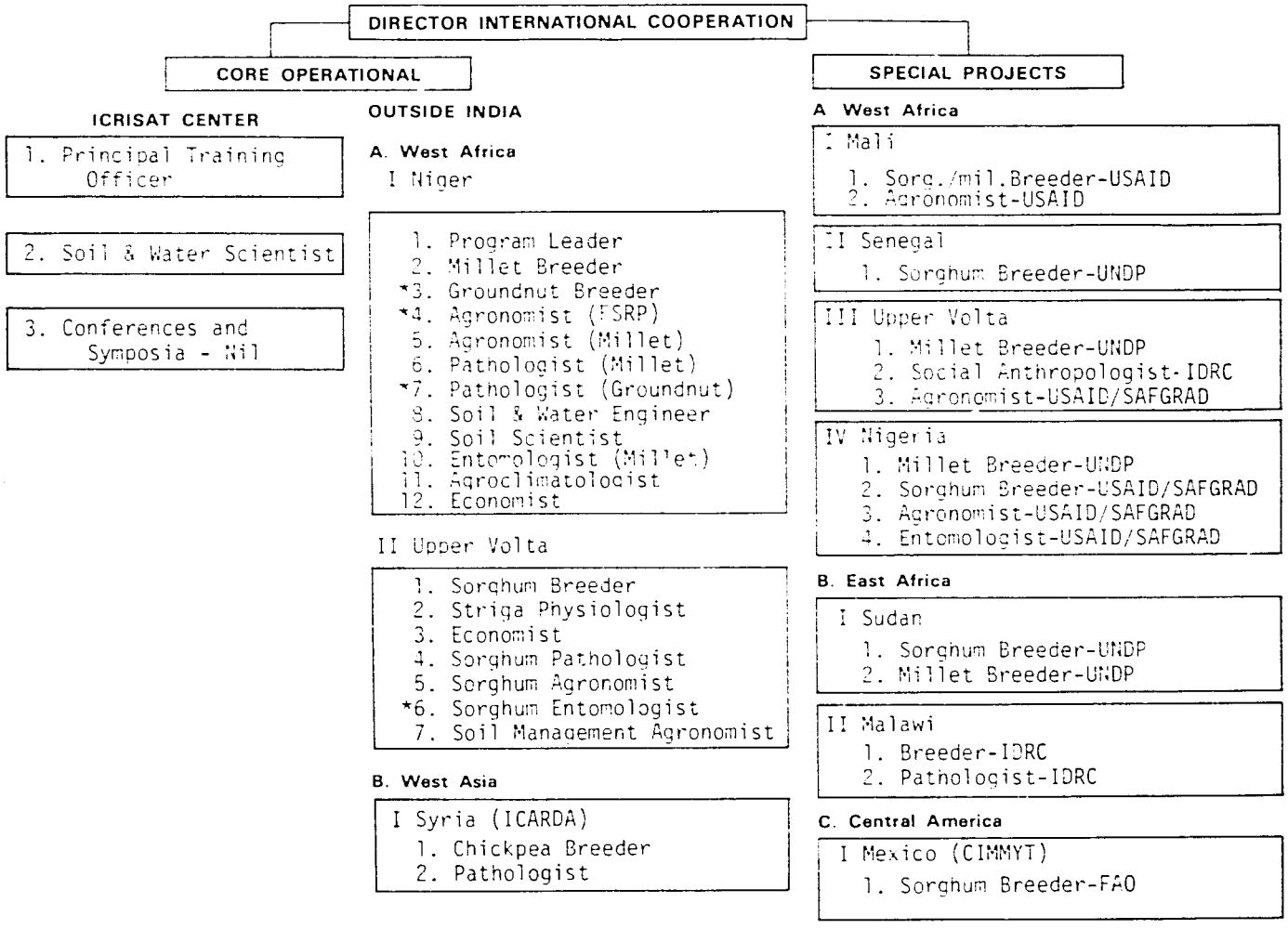


Figure 6. Staff organization under Director for International Cooperation.



Quarantine Programs mainly support the crop improvement programs; the first two also conduct some research.

The Training Program operates under a principal training officer who reports to the Director for International Cooperation. This Director is also responsible for a Visitors' Services unit and for the organization of workshops and conferences. A major responsibility of the Director for International Cooperation is the management of special projects and cooperative programs with other institutes and agencies in countries outside India.

Information Services, because of its wider responsibilities throughout the Institute, is supervised by the Director General. It provides support to all the programs and offices.

Administrative service divisions—Fiscal, Purchase and Supplies, Personnel, Physical Plant Services, Housing and Food Services, Transportation and Security—report to the Principal Administrator and provide support to all the programs.

5.2 Research Projects

The fundamental unit of research in ICRISAT is the research project. A project has objectives, specified methodology, and a specified duration and resource requirement (staff and material resources). One or more scientists often from different programs may be involved in each project, and they cooperate in an interdisciplinary effort. Projects are formulated at the subprogram level by the concerned scientists, keeping in view the goals of the program and the Institute. Program leaders integrate projects into the main themes and philosophy of the program. New projects are critically reviewed at the institute level at an In-House Review. After incorporation of the suggestions and guidelines given by the scientific faculty of the Institute, the revised projects are submitted to the Director of Research for scrutiny and approval. The mechanism of the In-House Review ensures proper assignment of priorities and helps in defining objectives, selecting methods and encouraging coordination.

The overall priority, goals, and achievements of different research programs are reviewed and discussed by the Program Committee of the Governing Board. This Committee is the Institute's highest technical committee for research. The recommendations of the Program Committee along with the observations of the Board help determine priorities, strategies, and resource allocation in the research programs.

5.3 Network for Core Program Research in India

For ICRISAT's core research program, the Government of India provided 1394 hectares at Patancheru near Hyderabad, Andhra Pradesh, but it was realized that a few stations in different environments would be essential to effectively select for wider adaptation, to screen for specific disease and pests, and to conduct off-season nurseries. With the support of the Indian Council of Agricultural Research (ICAR), agreements were made with several universities for research facilities. We are improving physical facilities at these locations to facilitate our work there.

The station at Bhavanisagar (Tamil Nadu Agricultural University) is at 11°N latitude and is proving extremely useful for research on sorghum and millets because of its direct latitudinal correspondence with some areas in Africa. The Groundnut Program is also using its facilities to screen for resistance to pests and diseases.

At the College of Agriculture, Dharwar (University of Agricultural Sciences, Bangalore) at 16°N latitude we are breeding and screening for resistance to downy mildew and charcoal rot of sorghum and carrying out disease research on groundnut.

At the College of Agriculture, Gwalior (JNKVV, Jabalpur) at 26°N latitude, the program is mainly concentrating on breeding of long-duration pigeonpeas. Facilities for limited mechanization of farming have also been provided. Gwalior is also proving to be a useful site for pearl millet and chickpea research.

Hissar (Haryana Agricultural University) at 29°N latitude, is representative of the large areas in northern India growing pearl millet in kharif (rainy season) and chickpea in winter. For millet, long days and high temperatures allow effective selection for yield and earliness. This station is also suited for short-duration pigeonpeas and for screening sorghum against borer and shoot fly, but strengthening of facilities is necessary to take full advantage of this environment.

For raising an off-season nursery of chickpea a small piece of land (about 2 ha) has been arranged at Taparwaripura farm, 35 km from Srinagar (33°N) with the assistance of the State Government of Jammu and Kashmir.

In addition to these five cooperative research stations, we have land-use facilities available at a few other university research farms for special purposes such as drought stress or disease hot spots. For groundnut research, we have made arrangements with the new National Research Center for Groundnut at Junagadh (Gujarat), which represents the black soil, groundnut-growing area in India. ICRISAT hopes to use this environment to evaluate germplasm and cultivars and to breed for disease resistance.

5.4 ICRISAT Network in Africa

The distinctive and varied agroclimatic and socioeconomic environments in Africa make it difficult to introduce agricultural technologies from elsewhere. This applies particularly to the biological and chemical innovations required to increase crop yields. Innovations developed in one area may not be broadly transferable due to the marked differences in rainfall, soils, and other ecological factors, not to mention the cultural diversities and local food preferences that have produced wide variations in the dominant and secondary food crops of different areas.

Accordingly, ICRISAT developed a cooperative network of interrelated programs in six African countries (Nigeria, Niger, Mali, Upper Volta, Senegambia, Sudan) and provides research material and training of staff to other countries.

The initial project in our African program was developed in West Africa under a 3-year UNDP project that was subsequently extended into a second and third phase. The prime objective was strengthening existing research

programs in development of higher-yielding cultivars of sorghum and millet that incorporated reliable and stable yield characteristics. Reliable yields presuppose inclusion of resistances to the principal insect pests, plant parasites, and diseases, and this continues to be an important thrust in this research. A further aim was to develop improved farming systems to fully capitalize on the crop improvement programs and ensure maximum utilization of moisture. Since intercropping is a feature of agricultural systems in Africa, this was a particular area included for research and economic study.

The ICRISAT Governing Board, recognizing the clear need for a long-term commitment to Africa, has adopted a broad plan for developing ICRISAT programs there (A Long-Term Plan for Developing ICRISAT Programs in Africa, 1979). This plan envisages centering core-funded ICRISAT research teams in Africa to support and extend the work of the cooperative network.

The ICRISAT Sahelian Center

ICRISAT's major location in Africa has been chosen in a typical millet-growing area near Niamey, Niger. It will strengthen our capability to study the unique features of the Sahelian area, which has a relatively low annual rainfall (600 mm) with low dependability, where the soils are sandy with low natural fertility, evapotranspiration rates are high, and growing seasons are short (75 to 120 days). It provides an important benchmark site in West Africa, particularly for research on pearl millet and groundnut improvement and on farming systems and economics. The work will focus on technology that is transferable to the farmer. The program will also include cooperative research with ILCA on the use and feeding of draft animals, with national programs on crop improvement and farming systems, and serve as a training ground for scientists. The center became operational in 1981 and is the only location in Africa at which ICRISAT has its own facilities.

The crop improvement program at the Sanelian Center should have two plant breeders for millet and groundnut, two pathologists, an entomologist and an agronomist. The farming systems program will have a soil and water engineer, soil scientist, economist, agronomist, and an agroclimatologist. Supervision will be provided by the ICRISAT Coordinator for West Africa under the guidance of the Director for International Cooperation. Supporting services include farm operations and administration and possibly genetic resources.

Kamboinse, Upper Volta

To meet the needs of cereal improvement and farming systems in the Sudanian ecological zone of Africa (about 800 mm annual rainfall) a team for sorghum improvement and farming systems research is stationed at Kamboinse, Upper Volta, at the research station of the Ministry for Higher Education and Research. The research team should include a sorghum breeder, pathologist, entomologist, agronomist, *Striga* physiologist, production agronomist, soil management agronomist, and an economist. A millet breeder works with the team as part of a UNDP special project. A social anthropologist is currently also part of the farming systems team through the assistance of IDRC.

Samaru, Nigeria

The need for sorghum improvement in the southern Sudanian ecological zone (1200 mm annual rainfall) in Africa is catered to by the establishment under SAFGRAD of a sorghum team at Samaru, Nigeria, through an agreement with the Institute of Agricultural Research at Ahmadu Bello University. The team consists of a sorghum breeder, entomologist, and agronomist. A millet breeder is also located at Samaru in a UNDP special project.

Southern and Eastern Africa

We have posted two staff members in Malawi to initiate a regional groundnut research program, which will capitalize on the germplasm base and resistance lines identified at ICRISAT Center, Patancheru. This program will serve as the focus for increased input into countries of both the eastern and southern regions of the continent on this important crop. There is increasing interest in southern and eastern Africa for ICRISAT regional programs on sorghum and millet. Work on these crops will be initiated in the first few years of the 10-year period.

5.5 Cooperative Linkages

ICRISAT does not expect to conduct all the research needed to attain the stated scientific objectives. Some strong national programs already exist and others are gaining strength. We serve national and regional programs in the developing world and seek to cooperate with programs in all parts of the world to mutual advantage.

Developing cooperative research ties with our client institutions and their scientists is a most effective way of ensuring the use of our research output. Linkages with the All India research networks have already been described. In addition, ICRISAT scientists cooperate with their colleagues in several Indian universities.

In Africa we are working closely with national scientists at research facilities of their government and we are cooperating on special projects with SAFGRAD, USAID, IRAT, CILSS, GTZ, the EEC and other bilateral and regional programs in SAT countries.

The cooperation we receive from national plant quarantine services is essential to the operation of multilocational trials and nurseries and the collection and distribution of germplasm. We have been particularly fortunate in the cooperation we have received from the Plant Protection Training Institute which has been given the authority by the Government of India to handle the movement of plant materials to and from ICRISAT.

Mentor Institutions

ICRISAT has developed a substantial network of wise counsellors among the universities of the developed and developing world. With financial assistance from several governments we have developed cooperative programs with universities in the UK, USA, West Germany, Canada, and the Netherlands, and

with national research institutes in the UK, Japan, and New Zealand. For several years IRAT has financed the direct costs of our West African Coordinator and this is leading to increased possibilities for future cooperation between ICRISAT and IRAT.

Numerous research institutes are working independently on problems of importance to their own researchers that are also important to ICRISAT. One of the responsibilities of our principal scientists is to keep in touch with these activities and to catalyze more work of this type.

Intercenter Linkages

ICRISAT has developed intercenter linkages with the international agricultural research centers with which we have common interests. The most effective of these has been with ICARDA in Syria. Because ICARDA and ICRISAT have common interests in chickpea, we have worked out a cooperative arrangement for research on this crop. ICRISAT has posted a chickpea breeder and pathologist at Aleppo who work with and are supported by ICARDA pathologists, microbiologists, and entomologists with responsibilities not only for chickpea but also for other leguminous crops. We have agreed that ICARDA will work on the kabuli type of chickpea, which is grown throughout most of the world, and ICRISAT will work on the desi type, which grows in India and Pakistan. The program has made excellent progress since it was implemented in May 1978.

CIMMYT is providing facilities to ICRISAT's sorghum breeder who is carrying out the program of research for high-altitude sorghums and for sorghums in Central and South America generally.

In Upper Volta an IITA cowpea breeder works side by side with ICRISAT and national scientists at the Kamboinse Research Center. In Upper Volta and Nigeria ICRISAT and IITA have separate contracts with the SAFGRAD program but work together under the AID/OAU-STRC coordinating mechanism.

ICRISAT and ILCA have developed cooperative arrangements for research in the Sahelian zone of Africa.

Biological nitrogen fixation is a matter of common interest to ICRISAT, IITA, CIAT, IRRI, and ICARDA, and we have good linkages for exchange of information and joint planning.

The UN Family of Agencies

The international agricultural research centers are not members of the UN family of agencies, but they have many attributes in common with those agencies. FAO, UNDP, and the World Bank are the three sponsors of ICRISAT, and UNDP is one of its major donors.

Apart from donor-client relationships with UNDP the main cooperative linkages developed so far have been with FAO. These relate particularly to the IBPGR and TAC, for which the Secretariats are provided by FAO; the Land and Water Development Division, to which ICRISAT is providing agroclimatological input to a global crop potential study; and the Plant Production and Protection Division, which provides advice and comment on a developing

pest-management program in Africa. Discussions have also been held concerning formal cooperative linkages with field projects of FAO, but nothing has as yet developed along these lines. We do provide plant materials upon request to several FAO field projects.

6. Resources

6.1 Staffing Guidelines at ICRISAT Center

Staffing at ICRISAT Center recognizes the global relevance of its research and training activities.

Each program at ICRISAT Center is headed by a program leader with a principal scientist in charge of each subprogram. The sorghum and millet breeding programs with their global reach each have an additional principal plant breeder to strengthen the research efforts.

Every principal scientist works with one to three scientists trained in different aspects of the scientific discipline covered by the subprogram and recruited nationally. These are well-trained scientists who generally have Ph.D. degrees. After a few years at ICRISAT many of them find international level positions within the IARCs or other international agencies. Every scientist is provided one to three scientific support staff members (Research Technician, Technical Assistants, Field Asistants, or Laboratory Assistants) and each subprogram has the services of clerical staff.

The crop improvement programs and the farming systems program each have about 40 to 50 regular daily-rated workers to help in the manual operations in the field or laboratory. Temporary daily-rated workers also are employed for a few days to a few weeks as dictated by the needs of the program.

Staffing in the training program follows the same general pattern as is found in the research programs. The Principal Training Officer is supported by three training officers and ten support staff, with a higher proportion of clerical and secretarial staff and lower proportion of technical staff than the research programs.

Research and administrative support programs and divisions are headed by principal staff or senior nationally-recruited professionals. They are provided with the requisite supervisory and non-supervisory staff.

6.2 Staffing Guidelines in the Cooperative Program

The staffing patterns for ICRISAT Center are neither possible nor necessary for ICRISAT's Cooperative Programs. In each regional crop improvement team there is a principal breeder and, if funds permit, a pathologist and agronomist/physiologist. A smaller number of entomologists, generally concentrating where possible on a single crop, serve several regional teams. Other principal scientists are added according to specific needs.

In the farming systems team at the ICRISAT Sahelian Center we will have a soil and water engineer, soil scientist, agronomist, economist, and an agroclimatologist.

Each principal scientist is supported by one technician plus two or three field helpers and daily-rated labor. The team also has clerical and secretarial support. In West Africa we have recently been able to post a principal administrative officer to assist the several teams there in setting up and maintaining the necessary administrative services and we hope to add a farm manager to the Sahelian Center.

The staffing requirements for the regional programs proposed by the various research programs are substantial. Each regional crop or farming systems team would contain two to four principal scientists plus a small number of principal support staff providing technical, administrative, and field assistance.

Regional programs in West Africa have been commenced using special project funds. Core program funding has been requested only after two or more project phases have adequately revealed the requirements for long-term commitments. This pattern of funding will be continued over the next 10 years.

6.3 Non-Salary Costs

Over the last few years the ratio of salary (total emoluments) to non-salary costs has increased and now exceeds 1.0. This has occurred in spite of decreased numbers of man-years at ICRISAT Center. The reasons are two-fold. Total donor contributions have not provided adequate adjustments for inflation in salaries and wages, leaving less money for other operational costs. Also expanding operations in Africa has introduced a much larger emolument bill for post allowances, housing costs, etc., and higher costs for technical, administrative, and field staff.

Our ability to conduct the work of ICRISAT well, to take advantage of opportunities, to explore new ideas, to respond to our clients' needs are critically dependent upon our retaining adequate non-salary funds.

We must, therefore, maintain a favorable ratio of salary to non-salary costs, preferably below 1.5.

Travel costs as a proportion of operational costs are rising slowly over the years. It is expected that this rise will need to continue as we expand the regional programs, some of which will be based at ICRISAT Center. Travel is not likely to exceed 10% of operational costs at any time.

6.4 Capital Requirements

Major capital construction at ICRISAT Center will cease with the completion of our Phase II building program in 1982. Future capital requirements will be concentrated on greenhouses and screenhouses or equipment replacement. In accordance with CG requirements equipment replacement will appear in the operational budget. A substantial capital investment will be required to develop the ICRISAT Sahelian Center. The land allocated by the Government of Niger is 45 km from Niamey, on an unpaved road, without power, telephones, developed water resources, or other utilities. Although the buildings planned are modest, construction costs will be much higher than in India. ICRISAT will seek construction funds from donors other than the CGIAR.

In all other locations ICRISAT will conduct its operations from national or state experiment stations. Most of the costs appear in the operational budget, but some captial funds for buildings, equipment, vehicles, and station development will be necessary.

6.5 Resource Requirements Over the First 5-Year Period

Operational requirements from 1981 to 1986 in constant dollars and based upon guidelines provided by the Secretariat of CGIAR are given in Table 9. The requirements for principal research positions for core-operational and regional activities over the same period are shown in Table 10. Several of the positions in this table are funded from special project funds. Requirements for capital funds for the period 1981 to 1986 are shown in Table 11.

Table 9. Operational requirements 1981-86 (US $'000)

	Actual	Curr.Est.	Proposed Budget		Projections	
	1981	1982	1983	1984	1985	1986
1. MAJOR ACTIVITIES						
a. Research Programs						
Farming Systems	954	1,074	1,279	1,443	1,600	1,681
Sorghum	1,002	1,043	1,189	1,570	1,799	1,882
Millets	770	994	1,094	1,190	1,301	1,357
Pulses: Chickpea & Pigeonpea	1,187	957	1,044	1,112	1,175	1,218
Groundnut	688	656	736	1,188	1,358	1,431
Economics	520	587	578	600	640	670
Subtotal	5,121	5,311	5,920	7,103	7,873	8,239
b. Research Support Service Activities						
Office of Dir. (Res.)	108	127	137	143	150	155
Plant Quarantine	62	53	54	58	60	61
Genetic Resources Unit	292	269	285	294	389	422
Biochemistry	153	141	153	163	176	183
Farm Dev. Operations	529	523	612	856	836	879
Lib. & Documentation	132	145	151	156	189	192
Information Services	420	339	353	370	392	413
Computer Services	132	114	125	136	149	158
Statistical Services	66	70	73	77	83	87
Subtotal	1,894	1,781	1,943	2,253	2,424	2,550
Total Research Activities	7,015	7,092	7,863	9,356	10,297	10,789

Continued

Table 9. *Continued*

	Actual 1981	Curr. Est. 1982	Proposed Budget 1983	Proposed Budget 1984	Projections 1985	Projections 1986
2. INTERNATIONAL COOPERATION ACTIVITIES						
Office of Dir. (Intl. Coop)	173	186	202	305	313	327
Training & Fellowships	508	330	414	430	431	433
Conferences & Symposia	150	104	195	195	195	195
Total	831	620	811	930	939	955
3. ADMINISTRATIVE SUPPORT						
a. General Administration	1,169	1,123	1,190	1,287	1,347	1,399
b. General Operations, including contingency	2,999	3,217	3,009	3,222	3,501	3,741
Total	4,168	4,340	4,199	4,509	4,848	5,140
Grand Total - Core Budget	12,014	12,052	12,873	14,795	16,084	16,884

Table 10. Principal research positions for core research and cooperative programs in 1981 and projects for 1984.

Program	ICRISAT Center 1981	ICRISAT Center 1984	Cooperative Programs 1981	Cooperative Programs 1984
Farming Systems	7	8	5	8
Sorghum	5	5	8	10
Millet	5	5	7	10
Pulses	6	6	2	2
Groundnut	5	6	-	4
Economics	3	2	3	3
Genetic Resources	2	2	-	-
Biochemistry	1	1	-	-
Total	34	35	25	37

Note: Cooperative Programs include some positions funded by special projects.

Table 11. Requirements for capital funds 1981-86 (In US $'000)

	Actual	Curr. Yr	Budget		Projections	
	1981	1982	1983	1984	1985	1986
1. Land & Improvements	52	15	29	250	115	125
2. Bldgs & Site Improvements	853	1,145	502	271	326	179
3. Equipment	106	325	220	316	681	860
4. Consulting Services & Others	143	101	50	-	-	-
5. West Africa Capital	232	250	580	660	950	720
6. Contingencies	-	14	39	43	62	57
Total	1,386	1,850	1,420	1,540	2,134	1,941

Positions and operational budgetary requirements appear to reach something of a plateau in the last 2 years of the period, but it is likely that regional programs commenced with special funds in eastern and southern Africa will cause some increase in positions above the projections shown in Table 10.

Conclusion

Ten years after the founding of ICRISAT, we feel that we are well on the way toward carrying out the mandate given to us by the Consultative Group in 1972. Our research programs are well established—in the Indian subcontinent, where we started and have made substantial progress; in Africa, where we are developing improved cereals that will grow under the harsh environmental conditions of the drought-prone Sahel and where we will increasingly focus attention on problems in eastern and southern Africa as well; and in Central America, West Asia, and other semi-arid areas where rainfed agriculture produces the food necessary for life. We have found in our research some things that will work, and some that will not, and we have incorporated the positive traits into new crop lines that are now beginning to reach farmers' fields. The gene bank that we have established at ICRISAT Center serves breeders throughout the world.

We realize that this is only the start toward meeting the challenge. We know that, no matter how effective and productive the crop lines and farming systems we develop, there may not be a "Green Revolution" in

the conventional sense in the semi-arid tropics--primarily because of the lack of water and fertilizer. But we are confident that the technology we are developing can avert disaster and eliminate food shortages if it is implemented and supported by national governments. We can only catalyze technological change through the national scientists and organizations that must bring about whatever transformation is to take place in SAT agriculture.

We have made good progress toward enabling millions of small farmers of the SAT to increase their present production of our five mandate crops with high-yielding varieties that will be resistant to pests and diseases, and capable of withstanding moisture stress and other environmental factors that limit crop yields. And if we can sustain that progress through the 1980s and beyond, ICRISAT will achieve its goals and justify the faith of its founders.