Revised Draft

ICRISAT in the Eighties
A 10-Year Plan

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ICRISAT

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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

ICRISAT was given an initial mandate to improve four crops vital to life in the semi-arid tropics (SAT): sorghum, millet, chickpea, and pigeonpea. A fifth crop, groundnut, was added to the mandate in 1974.

The mandate of ICRISAT is to:

1. Serve as a world center for the improvement of *grain* yield and quality of sorghum, *millets*, 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 *with the object of ensuring that proven beneficial new technology and innovations developed by ICRISAT are adopted at the farm level as quickly as possible.*

1.2 The Basis for the Mandate

a. The Semi-Arid Tropics (SAT)

Based on 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 (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%).

b. The Mandate Crops

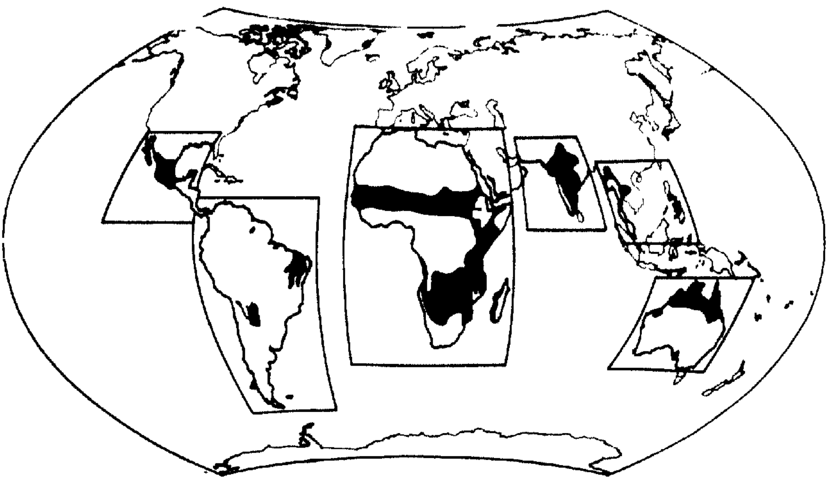
Sorghum and pearl millet are the fourth and fifth most important cereals of the world. Together they rank second to rice in cultivated area in developing countries. Generally, they are the cereals of the poorest countries and the poorest people in those countries. In assessing priorities in 1975 the 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, among cereals, rank first in calorie intake in Africa, and third in Asia and the Middle East. 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.

Recent reports predict substantial deficits in cereals in the developing world by 1990. The International Food Policy Research Institute(IFPRI) estimates India will then have a 20 million tonne shortage of cereals if present trends of production, population growth, and demand for food continue. The African SAT countries, where food production per capita is declining, will have per capita deficits nearly ten times as great as India. The annual rate of growth of sorghum and millet production in developing countries has been only 1.8% and 1.2% per year, respectively, whereas the demand has increased by more than 2.5% annually.

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 source of cash for producers.

These factors make it imperative to greatly increase present production.

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



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 India, which produces 95% of the pigeonpeas and 80% of the chickpeas.

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. 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.

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.

c. Technological and Socioeconomic Constraints in Rainfed Agriculture

Traditional agricultural systems in rainfed SAT areas have evolved over a long period to provide an adequate and secure harvest for farming families, given the environment. The technology is based on the use of traditional tools and both human and animal labor, as available. Present systems are not designed to give high economic returns and are subject to technological and socioeconomic constraints that limit food production potential.

Our research shows that 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 infrastructural facilities have a considerable influence on 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. Any 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 in irrigated and/or dependable rainfall areas. In recent years, there has been increasing concern about 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 have realized that the potential of the semi-arid tropics to produce food far exceeds present production levels. The potential for modern agriculture does exist.

d. 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 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 improve 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 but capable also 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 TAC's first priority objective 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 for 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

ICRISAT's immediate clients, the direct users of our outputs, are mainly the national scientists in SAT countries and, to a lesser extent, their extension and action agency counterparts.

a. National Scientists

National scientists are responsible for producing improved cultivars and new technologies for the farmers of their countries; ICRISAT undertakes research that contributes and complements their efforts. Our workshops and conferences are designed to obtain their inputs to our research planning. Research scientists and their technicians, particularly from Africa, comprise most of our trainees. Our cooperative programs are aimed at strengthening their research institutions.

We emphasize what they 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 genetic diversity into the breeding materials we make freely available to national scientists. We test advanced materials over our international network of multilocational trails. The international networks for millet and sorghum are particularly well-developed.

As an international institution, we are able to explore more thoroughly new techniques of plant breeding, or old techniques in new contexts.

Because of our focus on the small farmer we emphasize in our research resistance to diseases and pests and major stress factors such as low fertility and drought. We are able to pursue difficult problems with great concentration and with sufficient resources. For example, ICRISAT is trying to introduce resistance to shoot fly in sorghum, ergot in pearl millet, *Heliothis* in pigeonpea, *Ascochyta* blight in chickpea, and *Cercospora* leaf spots in groundnut. Tolerance to drought is a priority objective in our research on sorghum, millet, and groundnut. We give highest priority to problems common throughout the SAT, leaving more specific problems to the national scientists.

We utilize a multidisciplinary team approach and extend it to economic and anthropological as well as biological and physical research. It helps us maintain focus on the problems of small farmers.

b. 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 will continue to assist in strengthening these institutions.

We have established cooperative agreements in crop improvement research with universities in Tamil Nadu, Karnataka, Madhya Pradesh, and Haryana. Our on-farm research is being conducted in cooperation with two agricultural universities in the state of Maharashtra and one each in Andhra Pradesh, Gujarat, and Madhya Pradesh.

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.

c. Extension and Action Agencies

In Africa, much 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 wet-dry semi-arid tropics of India has reached the stage where it must be tested on-farm and in pilot projects. ICRISAT will advise extension and action agencies which wish to use this technology. For example, the State Department of Agriculture of Andhra Pradesh has undertaken a cooperative project with ICRISAT to implement this technology in one village in Medak District, in which ICRISAT Center is also located. Training is being given to the state agricultural officers through this project so that they may then implement the technology more widely through the state.

The ICRISAT Governing Board has established a Transfer of Technology Committee to determine which research results are appropriately transferred through extension and action agencies.

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.

ICRISAT Center is within the dry semi-arid tropics. The research work at the Center, however, is designed to serve the entire geographic region of ICRISAT's mandate. To ensure that ICRISAT materials and concepts can be developed simultaneously to the benefit of the entire region, without the necessity of meeting intercountry quarantine restrictions, the Government of India agreed to assist ICRISAT in establishing cooperative agreements with four agricultural universities to provide us with experimental locations on a north-south axis throughout India. The locations are in the states of Haryana, Madhya Pradesh, Karnataka, and Tamil Nadu

Over the next 10 years ICRISAT will develop *a larger regional program*. The more mature IARCs have already reached this stage as is well-documented in the TAC Stripe Review of Off-Campus Activities (1980). 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 the first priority region for sorghum, pigeonpea, chickpea, and groundnut. Subregions within this region have also been identified. The region will be served by ICRISAT Center and the cooperative research stations within India (particularly at Hissar and Gwalior).

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 hope to 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 areas 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, and the University of Queensland, Australia.

2.4 Priorities among Programs

After 10 years of growth the priorities among programs are well established and can be judged from current 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) and will be maintained over the next 10 years. Forward projections for all programs 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 will be high under these conditions. In these circumstances, the small farmer needs stable, resistant or tolerant cultivars with yields consistently higher than traditional varieties 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.

ICRISAT, at least until 1980 when funds became limiting, was able to operate on a large scale to explore the germplasm in depth, to screen the large number of lines necessary to locate useful characteristics and superior varieties, and to develop simple screening techniques. We are able to run multilocational trials on an international basis to test both resistances and more finished cultivars.

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.

We will emphasize disease and pest resistance and stress tolerance, and ensure that these factors are durable and that yield potential is retained. This involves developing screening techniques for their identification, locating 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 consumer preferences particularly of eating and cooking quality. It will be undertaken jointly by the Crop Improvement Programs and the Biochemistry Division.

Many of the materials and techniques developed at ICRISAT will be useful to national research systems but will require local adaptation if they are to become locally effective. ICRISAT will have to respond increasingly to this need through training and cooperative research programs. 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 some service activities such as regional crossing programs. Likewise, we may have to cooperate with the agronomic research programs to exploit the potential of currently available and new cultivars, and cropping system and crop management technologies.

3.2 Crop Improvement Priorities

Sorghum

The average yields of sorghum (*Sorghum bicolor* [L.] Moench) in the SAT are only 800 kg/ha; they are around 3400 kg/ha in non-SAT market economies.

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 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.

It has been difficult to develop reliable screening techniques for *Striga* resistance. The main effort has been shifted to West Africa where this is a major limiting pest. Progress has been made, both in developing screening procedures and in learning more about pest-management techniques.

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. This is also the approximate demarcation between SAT and non-SAT zones and food and feed zones. 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.

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

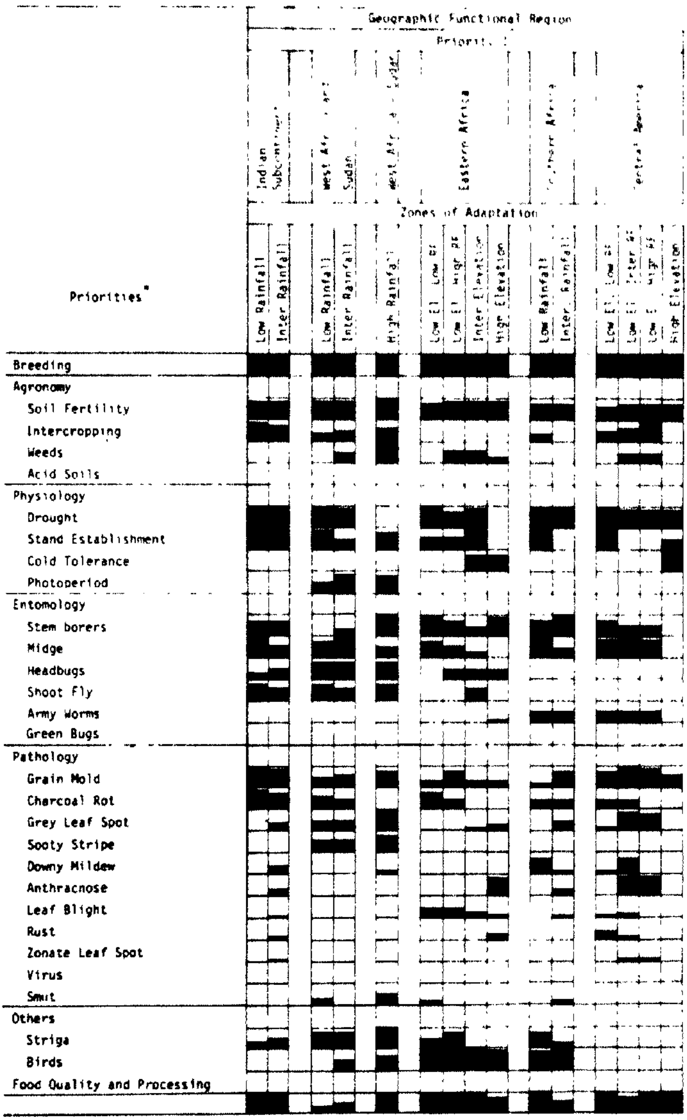
Research priorities have been identified for the various zones of adaptation for each geographic functional region and are shown in Table 2. The following problems will be addressed:

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 phenotypes in intercropping.

3. Developing techniques for identifying source material and incorporating resistance traits into agronomically elite lines for moisture, temperature and nutrient stress, grain molds, charcoal rot, downy mildew, leaf diseases, stem borers, midge, shoot fly, head bugs, and *Striga*.

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

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

Functional region	Area (Millions 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, Senegal, Sudan, Mali, Upper Volta)	13.4	654	Research agencies in the region such as USAID, IRAT, FAO, IDRC, ICIPE, INTSORMIL, and many national programs.
West Africa, high rainfall areas	22.9	655	
Eastern Africa and Yemen (Ethiopia, Kenya, Tanzania, Yemen, etc.)	6.2	956	
Southern Africa (Zimbabwe, Mozambique, Malawi, Botswana, etc.)	0.8	758	Developing research programs by SAFGRAD, CILSS, Institut du Sahel.
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	
South East Asia	0.5	1183	
Mediterranean - USSR			
Contributing Regions			
Temperate America	7.9	2508	National
Oceania (Primarily Australia)	0.4	1812	programs

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

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, the All India Coordinated Sorghum Improvement Project, and national programs of other countries.

Likely Achievements

1. Improvement and stabilization of screening procedures for priority traits of economic concern. Screening for some grain molds is now satisfactory and procedures are being developed for others. screening for shoot fly has also been developed but new traits, contributing to resistance, will be available soon. Procedures for screening for resistance to stem borer, midge, charcoal rot, and leaf diseases should become stable and satisfactory. The situation with *Striga*, and with birds in eastern and southern Africa, is more questionable. We expect to see an increasing input to evaluate sorghum for food in different parts of the world.

2. Identification of source material and incorporation of priority traits into elite varietal material. This process has begun, particularly with reference to resistance to grain mold and improving food quality. We expect that we will develop during this period agronomically good lines carrying resistance to various diseases and pests but will still need further input to develop lines with combinations of these traits.

3. Identification of useful hybrids, synthetics, and varieties for selected areas and better knowledge of crop management. We think that, as in India, the hybrids would start becoming prominent in Senegal, Mali, Sudan, Ethiopia, Nigeria, and Tanzania by 1985 and synthetics and improved varieties in many countries in the latter part of the decade.

Funding Implications

If funding improves, as seems likely, we will develop an international network of activity including scientists in several geographic functional regions. We will also increase input 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 F1 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 input on *Striga* in India as well as Center activity for some leaf diseases. A decreased input in breeding at ICRISAT Center is possible if this activity is strengthened in other geographical regions through core or special project funds.

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 Commonwealth Overseas Pest Research Organization, and the Max Planck Institute. Additional linkages are indicated in Table 1; cooperation with SAFGRAD, particularly, is developing at this time.

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 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 ergot, and distributing it extensively to the national programs, particularly in India.
- Producing open-pollinated varieties that are less susceptible to downy mildew and ergot; these have been produced by using recurrent selection from populations that have given over 90% of the yield of commerical hybrids.
- Developing and transferring to national programs large-scale field screening techniques for reliably selecting resistances to downy milew and ergot and distributing resistant material
- Showing that at low to medium yield levels, grain protein content can be improved without impairing selection for increased 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

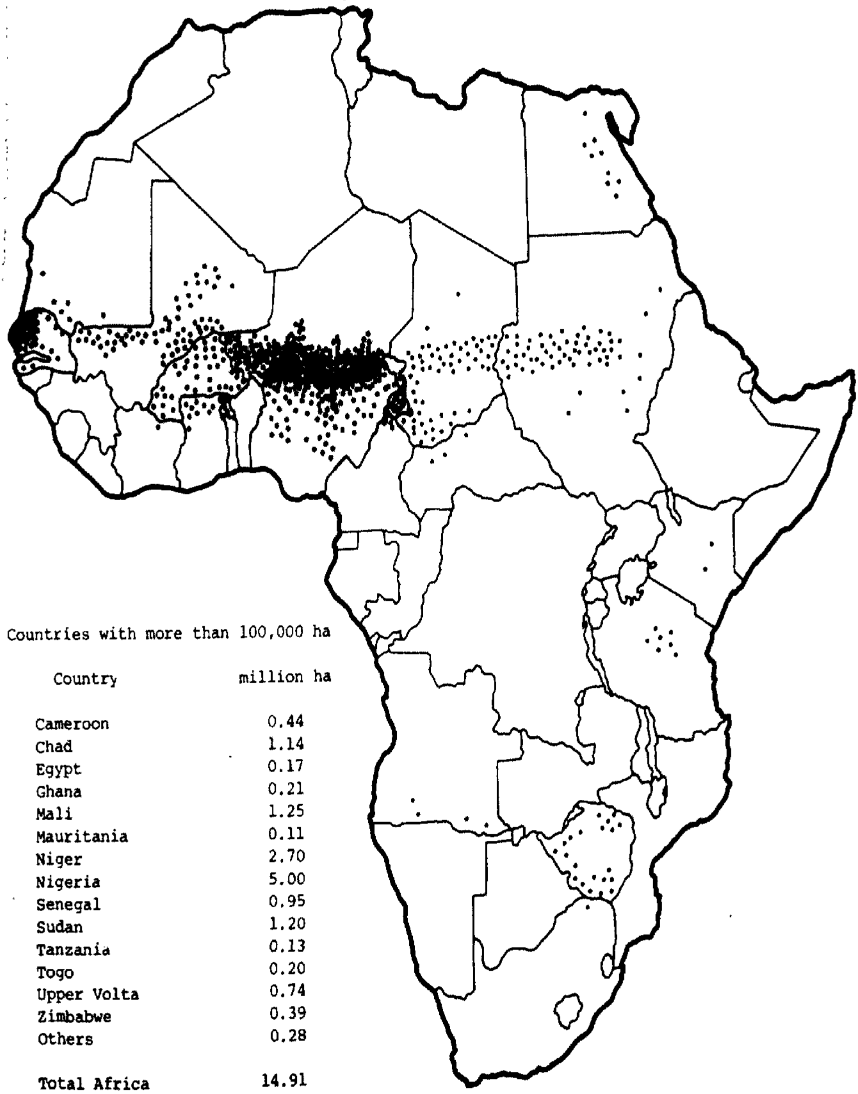
All four geographic areas of pearl millet production (Table 3) are in developing countries and therefore of concern. Two areas comprising Zones I and III may be identified as high priority (Figs.2, 3). Indeed, within Zone I, several Sahelian countries—Senegal, Mauritania, Mali, and Niger—with a total millet area of 4 million ha, have been identified as most dependant on pearl millet. These countries face the probability of a chronic food shortage in the next decade.

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. WEST AFRICA Cameroon, Ghana, Mali, Mauritania, Niger, Nigeria, Senegal, Togo, Upper Volta, Sahelian part of Sudan	1	11.64	620	UNDP, USAID, SAFGRAD, CILSS, IRAT, Inst. du Sahel, IDRC and national programs
II. N/CENTRAL, SOUTHERN & EASTERN AFRICA Chad, Egypt, Sudan, Tanzania, Zimbabwe	2	3.27	490	
III. N. INDIA & PAKISTAN Gujarat, Haryana, Madhya Pradesh, Punjab, Rajasthan, Uttar Pradesh & Pakistan	1	8.39	428	ICAR and universities
IV. CENTRAL & SOUTH INDIA Andhra Pradesh, Karnataka, Maharashtra, Tamil Nadu	2	3.31	423	

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

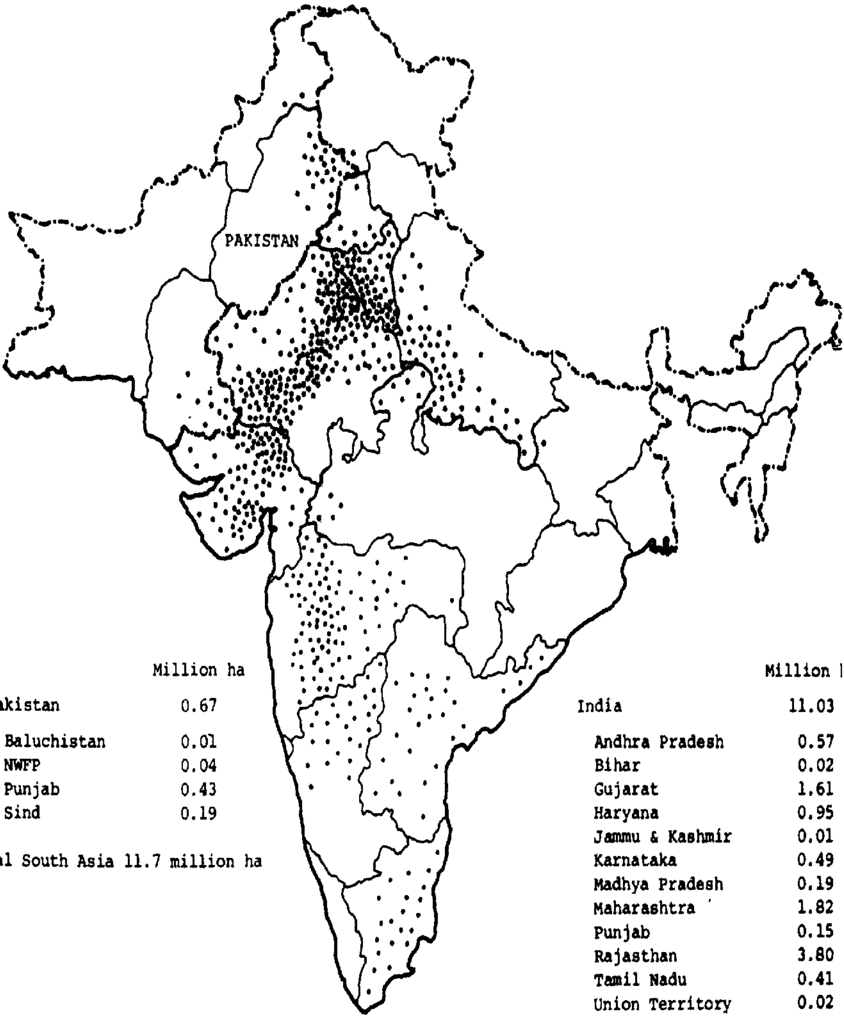
Figure 2. Reported area planted to pearl millet in Africa (1978), priority 1 zones in yellow.



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 1 zones in yellow.



	Million ha
Pakistan	0.67
Baluchistan	0.01
NWFP	0.04
Punjab	0.43
Sind	0.19

tal 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

Research Priorities, Strategies, and Goals

The major thrusts in research will 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 techniques for detecting 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

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 of 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 nitrogen fixation, we need to refine assay techniques to satisfactorily screen varieties/lines for this capacity. We hope that by 1985 techniques will be available to select for nitrogen-fixing capacity and incorporate it into advanced breeding material. 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 possible other methods of control—the biology and epidemiology of all four diseases, particularly downy mildew and ergot, will receive attention over the next 7 to 10 years. Special attention will be given to 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 likely that resistance factors must be bred into both parents of a hybrid, resistant hybrids may take some time to obtain.

Screening for resistance to smut and rust will continue, and effective levels of resistance are expected to be incorporated in advanced breeding material by 1985.

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 be seriously damaging and need attention; entomologists will determine their extent and severity 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 traits that reduce yield and contribute to instability of production. Major objectives are to incorporate into advanced breeding material sources of resistance to drought and disease, tolerance of low 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 parents are likely to be available by 1983.

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.

Work to date in West Africa has shown the existence of extremely high but variable pest and disease levels and has revealed the extent of the adaptation possessed by landrace varieties. These pest and disease levels have caused difficulty in evaluating the potential of exotic material, or even growing it to make crosses. However, at several locations relatively unadapted early-maturing exotic genotypes have equaled the grain yields of the local varieties. The landrace varieties have in general a poor harvest index, but unless this character is absolutely related to stability of grain yield such genotypes must be judged inefficient at converting existing growth potential into grain.

The high disease pressures and disease variability in West Africa, particularly for downy mildew, have been utilized in identifying resistance traits that are not location specific for reliable 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 where best to locate 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, effects of moisture stress, 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; and 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 increased 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 exceptional traits available in Napier grass (*P. purpureum*)—high growth rate, high nitrogen fixation, disease immunities and resistances.

In the event of a small decline in availability of funds we would effect economies by adjusting the volume of material handled, labor, and program travel. If funds decline further, priority would be given to maintaining research relevant to Zone I. Stress research would be reduced before research on yield potential. It must be noted, however, that pearl millet does not benefit from research in developed countries to the same extent as other 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 has possible practical applications. Collaboration on nitrogen fixation research exists with the University of Marburg, West Germany; Rothamstead, 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 95% of pigeonpea and 80% of chickpea is 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 rather limited. The ICRISAT program had to give highest priority to collection and evaluation of germplasm resources and the development of strategy for crop improvement.

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 types of pigeonpeas, which are in demand in the Caribbean and East Africa, 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 production. 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 the elite material. 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.

Chickpea scientists have developed techniques for screening against important diseases such as wilt, *Ascochyta* blight, and stunt, identified lines resistant to these disease, and distributed them to the national breeders for use in their breeding programs. Lines tolerant to *Heliothis* have been selected. The breeders have identified a male sterile line that could set the stage for the development of hybrids. The breeders have made crosses between tall and dwarf and kabuli and desi chickpeas and developed new possibilities of 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 Middle East region, we have started a cooperative research program with ICARDA on improvement of that type. The program is very useful for screening for *Ascochyta* blight resistance. It has also established that winter planting of chickpea increases production significantly over the present systems of planting in spring provided *Ascochyta* blight-resistant varieties are used.

Priority Regions

In both pigeonpea and chickpea, overall objectives are the identification or development of genotypes and characteristics countries to higher and stable yields of acceptable grain type under different 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 types responsive to higher inputs and suited for sole cropping systems that fit into rotation with wheat; materials suitable for the postrainy season in South and Central India; long-duration types for intercropping in central and northern India and eastern Africa; and medium-duration types for South India and West Africa.

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 pigeonpea are indicated in Table 4 and for chickpea in Table 5.

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

Table 4. Geographical functional zones along with area and yield of pigeonpea.

Priority/Zone	Area (million ha)	Average yield (Kg/ha)	Relevant cooperative research organizations
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	0.3	520	IDRC-supported legume program in Kenya
PRIORITY 2			
Zone III			
Dominican Republic[b] 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.

Table 5. 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, Middle East, 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 exports

[a]Source: FAO, 1978.

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 propduction 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 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

- Development of 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 of 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

- Development of elite disease-resistant materials.

- Screening of germplasm for additional sources of resistance to wilt, root rots, stunt, and *Ascochyta* blight in chickpea; to wilt, *Phytophthora* blight, and sterility mosaic in pigeonpea; and distribution of sources of resistant material through international nursery programs.

- Study of the influence of cropping systems on the incidence of soilborne diseases.

- Development of projects on emerging disease problems such as *Alternaria* blight on postrainy-season pigeonpeas.

- Epidemiological investigations of chickpea and pigeonpea diseases and survey of potential disease problems.

3. Pest stress management

- Screening of germplasm and breeding material for resistance to *Heliothis*.

- Intensification of research on ecology of important pests, including the study of potential pest problems and pest management practices.

- Development of a package of practices for pest management, the target species being *Heliothis* and podfly for pigeonpea and *Heliothis* for chickpeas.

4. ***Nitrogen fixation***

- Study of quantity and quality of *Rhizobium* strains in farmers' fields and their relationship to inoculation requirements; development of methods of study of *Rhizobium* strains and legume hosts for improving nitrogen-fixing ability.

- Assessment of the contribution of chickpea and pigeonpea to the nitrogen nutrition of associated crops in intercropping and sequential crop rotation.

- Development of methods for production and utilization of inoculants.

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

a. Chickpea

- Improvement of potential and stability (resistance to diseases, pests, and physiological stresses) of yield of short-duration desi and long-duration desi and kabuli suited to peninsular and northern India.

- Improvement of yield potential and stability of kabuli types for West Asia.

- Development of medium-tall chickpea plants with high yield potential

- International distribution to national programs of segregating and pure lines

- Assessment of effectiveness of breeding methods and study of male sterility to explore production of hybrids.

- Inheritance studies to evolve more effective breeding strategies

b. Pigeonpea

- Improving 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 and East Africa.

- Development of hybrids and exploitation of heterosis for a range of environments.

- Development of dwarf pigeonpea with high-yield potential for better management conditions.

- Incorporation of resistance to the major diseases and the major pests, tolerance to salinity and waterlogging, and increased ability to fix nitrogen.

Likely Achievements

Most of the survey work will be completed in the first 3 years and development of methodology in the first 5 years. Elite material with high-yield potential and yield stability with resistance to the major pests and diseases would be available for creating an impact in the national programs in the latter part of the decade. We believe that some the new plant types will be emerging for national use before the end of the period.

Funding Implications

If resources increase, the program will expand its activities to include East Africa, West Africa, the Caribbean islands and other areas where demand for pigeonpeas is high. in the case of chickpeas, we will strengthen cooperative research in the North Africa-Mediterranean region and South America while continuing to emphasize that presently going on in India, Pakistan, Bangladesh, and Middle East countries.

If the available funding has to be reduced, then we will have to 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 is one 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 the University of Reading (chickpea physiology), University of Rothamsted (microbiology), Max-Planck Institute (entomology), University of Queenslan (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 in 1976 but significant research commenced only 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 staffings 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 and leafspot resistance; and development of laboratory facilities to test the *Aspergillus flavus* resistance and aflatoxin production; identification of new sources of rust resistance for large-scale hybridization programs.

- Identification of the thrips vectors of Tomato Spotted Wilt Virus (TSWV) and characterization of several groundnut virus diseases (including TSWV, Peanut Mottle Virus, and Clump Virus); developing agronomic techniques for controlling TSWV and identifying sources of germplasm resistant to others.

- Crossing of leafspot-resistant wild diploid *Arachis* species with the tetraploid cultivated 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 between different species of *Arachis*.

- 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.

Priority Regions

India and Africa emerge as the areas of greatest concern based on hectarage, production, consumption, and the contribution of the crop to the available fat in the human diet (Table 6). In the Indian subcontinent, 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% and groundnut oil contributes only 8% of the available fat in the diet.

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

Functional region	Area (million ha)	Average yield (kg/ha)	Relevant cooperating research program
PRIORITY 1			
1. Indian subcontinent	7.20	861	All India Coordinated Oilseeds Research Program exists; National Research Centre for Groundnut (being developed).
2. Western Africa	3.05	880	Strong national programs in Nigeria, Senegal, others need strengthening; IHRO in francophone countries; GTZ program in Ghana (new).
3. Southern Africa	1.16	690	Strong national programs in Malawi and Zimbabwe; other national programs need strengthening; IDRC oilseeds project in Mozambique (new).
PRIORITY 2			
1. Eastern Africa	2.24	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)	1.47	1102	Strong national program in Thailand, others need strengthening; possibilities of IDRC projects.
3. China	2.45	1174	National program (being developed - potentially strong)
PRIORITY 3			
1. South America	0.77	1023	Good national programs in Argentina and Brazil

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.

Thus the ICRISAT core research program will continue to focus attention on the Indian subcontinent and will shortly initiate a program in Africa. The present plans are to post a breeder and pathologist in Malawi, and this team will cover both eastern and southern Africa as part of their regional activities.

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.

A similar core-funded team of breeder and pathologist is proposed for West Africa in 1982. In this region the major producers are Senegal and Nigeria, which still have strong research organizations. Other important producing countries are Cameroon, Gambia, Mali, Niger, and Ghana but they need to strengthen their capabilities in plant breeding, pathology, and microbiology. The organization IRHO, based in Paris, has had a strong influence on groundnut research in the francophone countries of West Africa. The German aid agency GTZ, has recently funded a crop improvement program in Ghana with groundnut included as one of the crops. ICRISAT is cooperating with both these organizations.

The regions listed as second priority areas in Table 6 are other Asian countries including China. ICRISAT is already cooperating with most of the countries in this area by supplying breeding material and germplasm. With the present limitation of funds it is not intended, or planned, to set up core-funded ICRISAT programs in this region. However, UNDP and IDRC and possibly other agencies have an interest in funding oilseeds projects, and we will, for the present, cooperate with regional, bilateral, and national programs.

In South America production is dominated by two countries, Brazil and Argentina. Production in Brazil is declining due to competition from soybeans; in Argentina the production system is highly mechanized and in the hands of large farmers. We intend only to continue the supply of genetic material to this region and cooperate with the Genetic Resources Program and IBPGR in the collection of indigenous material, particularly primitive landraces and wild species.

Research Priorities, Strategies, and Goals

The high priority research targets for the next decade are:

Environmental stress

- Development of methodology within the next 5 years for screening for resistance to moisture stress, temperature stress, nutrient stress, and to study the interrelationship of these stresses.

- 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 diseases such as *Phoma*, *Leptosphaerulina*, and *Fusarium* in Africa.

- Intensification of research on *Aspergillus flavus* and other soilborne 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, and 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 them in breeding programs.

Breeding and cytogenetics

- Development and release of high-yielding rust-resistant lines, combined with a reasonable degree 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 high-yielding lines specifically for irrigated conditions in the Indian subcontinent, Southeast Asia, and Africa.
- Evaluation of all available wild species for the improvement of the cultivated groundnut.
- elimination of crossing barriers between useful wild species and the cultivated species through tissue culture and cytogenetic manipulation, and study of basic cytogenetic problems that may be hindering the progress of breeding programs.

Likely Achievements

Within the next decade, we should have available for national and regional programs material superior in terms of yield and yield stability. With the current rate of progress, and providing that the disease and pest spectrum remains constant, we should be able to provide advanced breeding material with high yield and resistance to rust, leafspots, and some of the insect pests and viruses. Where resistance is not available, or where such resistances may take longer than a decade to achieve integrated management practices will be developed.

Funding Implications

The Groundnut Improvement Program at present has two subprograms still in the development state—physiology and entomology. The other subprograms are complete and operational with integrated research projects designed to overcome the major constraints that presently limit groundnut production.

If extra funds become available, 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 which is caused by a *mycoplasma*. Likewise, the strengthening of the African teams by the inclusion of physiologists and microbiologists would be justified.

If funding becomes limiting then savings could be made by an overall reduction in future research effort. Specific 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 disease (caused by Tomato Spotted Wilt Virus) is being 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.

Linkages with Other Institutions

Presently we have strong links with North Carolina State University and other U.S. institutions and with Reading University (UK) in breeding, cytogenetics, disease resistance, and nitrogen fixation studies. We are cooperating with virus research institute in Japan, UK, USA, the Ivory Coast, and Nigeria and hope to develop strong links with the Virus Research Insititute in West Germany, the International *Meloidogyne* Project in North Carolina, and with Imperial College, UK, for research on races of rust and other fungal diseases. We intend to develop very close links with the proposed USA Title XII Peanut Program. We are strengthening our links with the National Research Center for Groundnut in India, and we already have close links with the Indian Directorate of Oilseeds Research.

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 are 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 65,000 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 America. A concerted effort will

[1] Proso millet (*Panicum miliaceum*), finger millet (*Eleusine coracana*), foxtail millet (*Setaria italica*) little millet (*Panicum miliare*), barnyard millet (*Echinochloa crusgalli*), and kodo millet (*Paspalum scrobiculatum*)

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

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	14,074	India, South, Central Africa, parts of Eastern Africa	Western, North Eastern, parts of Eastern and Southern Africa, Asia
Pigeonpea	8,815	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	12,332	India, Iran, Afganistan, Turkey, Israel, Spain and Mexico	East Africa, Ethiopia, Egypt, North West Africa, Western Asia, Algeria, Tunisia, USSR, Portugal, Argentina
Groundnut	8,363	India, U.S.A., Senegal	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	68,887		

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 a 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 we are envisaging 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 concepts that could be applicable to other socioeconomic-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 postrainy-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 will be given to on-farm research, although in Africa considerable center-based research will still be 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

Expected Achievements

- Adoption of watershed-based improved farming systems by farmers on deep Vertisols in the assured rainfall areas of SAT India.
- Better delineation of the SAT regions and characterization of agroclimatic zones.
- Further development of models to describe the soil-plant-atmosphere continuum.
- Improved capability for predicting the most appropriate cropping systems for a given environment.
- Clear understanding and further advances in research methodology.
- Design of efficient farm implements and equipment for satisfactory crop establishment and management.
- Quantification of the nutrient dynamics under improved resource management and cropping systems.
- Better understanding of the pest, weeds, and diseases and better management of problems in improved farming systems.

- Development of water-harvesting methods suitable for different environments and strategies to optimize the utilization of limited water.

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 simulating the effects that various technology and policy scenarios could have on

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

Research Projects	Priorities India	Priorities West Africa	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Analysis of traditional farming systems	1	1			1* and WA**								
Assessment of prospective technologies	2	2				WA							
Environmental use and social organization	4	4			WA								
Studies of traditional tanks	6	9			WA								
Mechanization studies	8	3			WA								
Risk studies	7	8		WA									
Market studies	5	5			WA								
Consumer preference analysis	9	6			WA								
Nutrition studies	10	10											
Adoption constraints	3	7						1 and WA					

* India

** West Africa

|---- ---→ Projects under way

|- -| Projects completed

|--------→ Projects being planned

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 organization 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 7 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 general 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.

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, Inservice Trainees, and Apprentices.

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.

In the future a larger number of trainees will be assigned for practical training and applied research to individual scientists in research programs as research scholars, research fellows, and international interns. They will also require courses in their areas of specialization and these will be developed using both traditional methods and modern technologies, such as video. The number of students and postgraduates for such training has been small, but the SAT country educational programs are beginning to obtain increasing number of graduates in agricultural sciences. This increased number of agricultural graduates will enable the Institute to provide more training programs and activities at an advanced level of skill development and practical application. Periods of attachment may be as short as a few weeks to pick up specific techniques, or longer to develop experience and skills in the range of techniques within a discipline.

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 audiotutorial 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 inservice 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 interships, research fellowships, and scholarships away from ICRISAT Center—and opportunity for inservice 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, 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, is planned for late 1981. This will examine the results of a similar broad spectrum workshop held in the early 1980s, when a broad strategy was planned. The successes and failures of plans charted at this conference will be used to determine strategies for the 1980s. The conference will cover all aspects of sorghum improvement and will ensure wide representation from developed and developing countries. Cosponsors have been obtained to ensure such wide representation.

ICRISAT will also host a smaller and specific workshop to highlight the importance of *Heliothis*, probably the tropical world's worst insect pest in agriculture. This pest is very catholic in its food preference tastes and has proved to be an intractable problem in spite of many years of concentrated research on the insect on individual crops. We believe a systems approach may assist in solving the problems with *Heliothis*. Other specialist workshops are already planned including one on agrometeorology of sorghum and millet, as requested by participants at a recent World Meteorological Organization Workshop.

Specialized small workshops will be held increasingly within developing countries. A workshop on *Striga* is planned in Upper Volta in 1981 and a further workshop is likely to be held on Socioeconomic Constraints to Development in West Africa, possibly in 1982. The former will be funded by IDRC and the latter is likely to be supported by both IDRC and IRAT.

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 serve the interest of scientists at ICRISAT Center but also operate 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 nonscientific 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 who is also the subprogram leader in the area of his specialization. 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, and entomology, except for Millet, which has no separate entomology unit. The Groundnut Program has virology and cytogenetics, and Millets and Pulses have N-fixation as additional subprograms. The entomology subprogram in Sorghum serves the Millet Program, and the N-fixation unit of Millet serves the Sorghum Program. The Farming Systems Program has subprograms on agronomy, 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 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 may be involved in each project, and they cooperate in an interdisciplinary effort. Projects are formulated at the subprogram level by the concerned scientist and the principal scientist, keeping in view the goals of the program and the Institute. Program leaders attempt to integrate various projects into the main themes and philosophy of the program. All 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

Figure 4. ICRISAT's Research Organization.

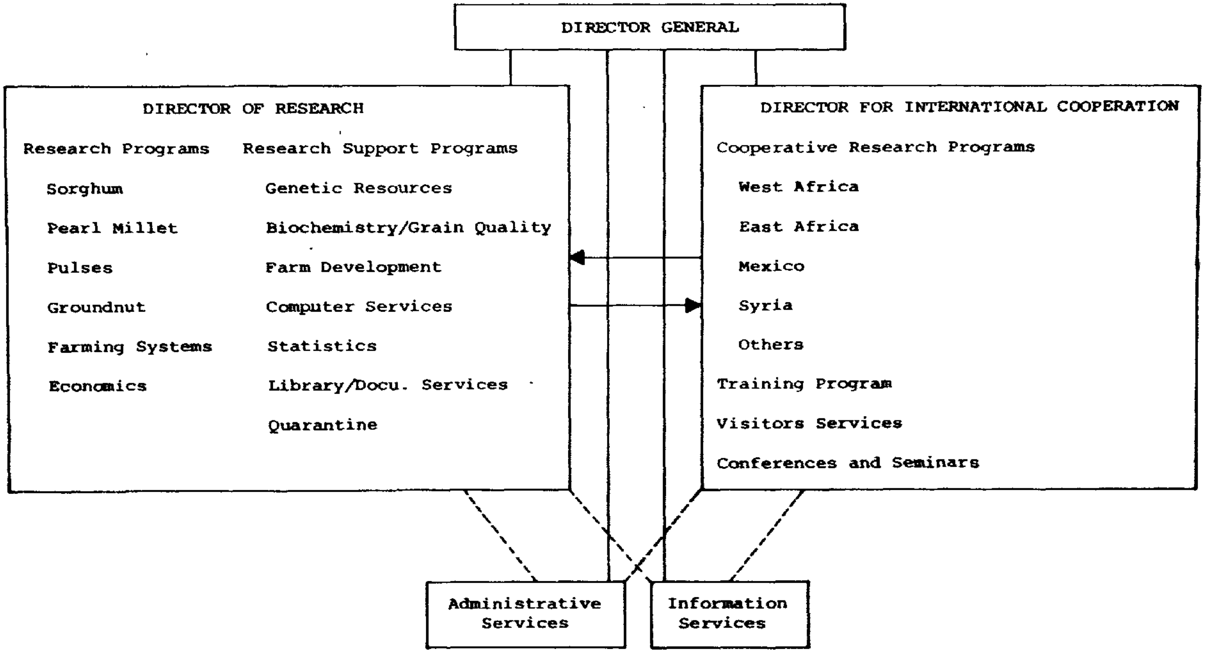


Figure 5. Research organization by programs under Director of Research (as of March 1981).

DIRECTOR RESEARCH
(Core Research Program)

1. SORGHUM
1. Program Leader and Breeder
2. Breeder
3. Pathologist
4. Physiologist
5. Entomologist

2. MILLETS
1. Program Leader and Breeder
2. Breeder
3. Pathologist
4. Physiologist
5. Microbiologist

3. PULSES
1. Program Leader and Pathologist
2. Pigeonpea Breeder
3. Chickpea Breeder
4. Physiologist
5. Entomologist
6. Microbiologist

4. GROUNDNUT
1. Program Leader and Breeder
2. Cytogeneticist
3. Pathologist
4. Virologist
5. Physiologist
*6. Entomologist

5. FARMING SYSTEMS
1. Program Leader and Climatologist
2. Land and Water Management Engineer
3. Farm Power & Equipment Engr
4. Cropping Systems Agronomist
5. Soil Physicist
6. Soil Chemist
7. Agronomist

6. ECONOMICS
1. Program Leader and Economist (Production)
2. Economist (Marketing)
3. Social Anthropologist

7. GENETIC RESOURCES UNIT
1. Program Leader and Germplasm Botanist (Cereals)
2. Germplasm Botanist (Pulses)
*3. Germplasm Botanist (G. nut)

8. BIOCHEMISTRY & GRAIN QUALITY
1. Principal Biochemist

9. QUARANTINE
+1. Quarantine Liaison Officer

10. LIBRARY & DOCUMENTATION
+1. Librarian

11. STATISTICS
1. Biometrician

12. COMPUTER SERVICES
1. Computer Services Officer

13. FARM DEVELOPMENT OPERATIONS
1. Manager

* New posts for 1982
\+ Locally recruited

Figure 6. Organization by programs under Director for International Cooperation (as of March 1981)

DIRECTOR INTERNATIONAL COOPERATION

CORE OPERATIONAL

ICRISAT CENTER

1. Principal Training Officer
2. Soil & Water Scientist 1
3. Conferences and Symposia - Nil

AFRICAN CORE

A. West Africa

I Niger

1. Millet Breeder
*2. Groundnut Breeder
3. Agronomist (FSRP)
4. Agronomist (Millet)
5. Pathologist (Millet)
*6. Pathologist (Groundnut)
7. Soil & Water Engineer
8. Soil Scientist
9. Entomologist (Millet)
10. Economist
11. Administrator

II Upper Volta

1. Sorghum Breeder
2. Striga Physiologist
3. Economist
*4. Sorghum Pathologist
5. Sorghum Agronomist
6. Sorghum Entomologist
7. Soil Management Agronomist

B. Middle East

I Syria (ICARDA)

1. Chickpea Breeder
2. Pathologist

C. Central America

I Mexico

1. Sorghum Breeder

SPECIAL PROJECT

A. West Africa

I Mali

1. Sorg./mil. Breeder - USAID
2. Agronomist - USAID

II Senegal

1. Sorghum Breeder - UNDP
2. Entomologist - UNDP
3. Project Manager - IRAT

III Upper Volta

1. Millet Breeder - UNDP
2. Pathologist - UNDP
3. Social Anthropologist-IDRC
4. Agronomist - USAID

IV Nigeria

1. Millet Breeder - UNDP
2. Pathologist - UNDP
3. Sorghum Breeder - USAID
4. Agronomist - USAID
5. Entomologist - USAID

B. East Africa

I Sudan

1. Sorghum Breeder - UNDP
2. Millet Breeder - UNDP

II Malawi

1. Breeder - IDRC 1982
2. Pathologist - IDRC 1982

*New posts for 1982.

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 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.

Research projects generally have durations of 3 to 5 years, towards the end of which they are critically reviewed. They are concluded when the objectives have been achieved. Cooperating scientists representing different disciplines are involved in each project. Funds are allocated by programs and sub-allocated to subprograms by the program leader. We have not budgeted funds by projects and we are not sure there would be any advantage in making such allocations. We have the apprehension that a project budget could encourage separatist tendencies and lead to demand for duplication of facilities, thus resulting in inefficient use of resources.

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 the University of Agricultural Sciences, Bangalore; Tamil Nadu Agricultural University, Coimbatore; Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur; and Haryana Agricultural University, Hissar, for providing facilities for research at Dharwar, Bhavanisagar, Gwalior, and Hissar, respectively. These cooperative research stations provide a range of environments and hot spots for screening disease and pest resistance to enable ICRISAT to fulfill its international mission without facing the problem of quarantine which would restrict the flow of material and also make the program much more expensive. We are improving physical facilities at these locations to facilitate our work there.

The center 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 where ICRISAT scientists carry out their core program under the supervision of their own staff, we have land-use facilities available at a few other stations for special purposes such as drought stress or disease hot spots.

For groundnut research, we will develop arrangements with the new National Research Center for Groundnut at Junagadh (Gujarat), which represents the typical 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, Senegal, 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 average 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 national programs and serve as a training ground for scientists. The station became operational in 1981 and is the only location in Africa at which ICRISAT has its own facilities.

The crop improvement program at the Sahelian Center will 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 Voltaic Ministry for Higher Education and Research. The research team consists of a sorghum breeder, pathologist, 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 Africa

We plan to post two staff members to southern Africa to initiate a 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 neighboring countries of both the eastern and southern regions of the continent on this important crop. It is expected that the team will be strengthened by the addition of a principal scientist to study the microbiological aspect of the groundnut crop. There is increasing interest in southern Africa for an ICRISAT program on other crops within ICRISAT's mandate, notably sorghum and millet. Work on these crops will be initiated in the first few years of the 10-year plan.

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 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 must develop cooperative arrangements for research in the Sahelian zone of Africa where the farmer and the pastoralists come together. The probable places for cooperative work will be the ICRISAT Sahelian Center and the ILCA station at Niono, Mali.

CIAT is interested in INTSORMIL developing, with ICRISAT participation, research in sorghum for the acid soils with aluminium toxicity in tropical South and Central America. If funds become available, we could develop joint interest in a cooperative program. 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 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. 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.

In addition, 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 and help in collecting plant data, selfing, pollinating, sampling, harvesting and threshing of grain, and preparation of seed samples. Temporary daily-rated workers also are employed for a few days to a few weeks as dictated by the needs of the program. Owing to the constraint of funds and rise in wages and prices, the number of daily-rated laborers that a program can employ is decreasing. The major emphasis is shifting to quality of labor rather than numbers.

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.

ICRISAT Center is now adequately staffed to fulfill its responsibilities. The normal real growth allowed an established center will be sufficient to take care of changing needs and increasing workloads.

6.2 Staffing Guidelines in the Cooperative Program

The staffing patterns for ICRISAT Center are neither possible nor necessary for ICRISAT's Cooperative Programs which concentrate on regional and—to some extent—national priorities. 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 management agronomist, a soil physicist or physical chemist, and an engineer

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.

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 twofold. 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 non-salary costs is rising slowly over the years (from 6.9% in 1979 to 7.5% in 1982). 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 non-salary 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 major 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 25 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.

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 1980 to 1984 taken from ICRISAT's mid-term budget report for 1981/1982 are given in Table 9. The requirements for principal staff positions for core-operational and regional activities over the same perod are shown in Table 10. Four of the positions (at Samaru, Nigeria, and at CIMMYT) in this table are currently funded from special project funds. Requirements for capital funds for the period 1980 to 1984 are shown in Table 11.

The tables show that allowances for inflationary costs are increasing, as is true for all the IARC's. It does not appear that the CGIAR system, which has achieved so much to date, will be able to respond effectively to future needs and requests from potential beneficiaries until worldwide inflation is reduced.

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.

Capital funds decreased in 1981 due to the severe shortfall of funds in that year, but increase again towards the end of the period. *Requirements are likely to continue at about the $2 million level for several more years.*

Conclusion

Nine 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, the Middle East, 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 our 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 pest 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.

Table 9. Operational requirements 1980-84.

	1980		1981		1982		Projections 1983		1984	
	MY	Cost	MY	Cost	MY	Cost	MY	Cost	MY	Cost
1. MAJOR ACTIVITIES										
a. Research Programs										
Farming Systems	8	980	7.75	1,349	11	1,458	12	1,684	12	1,790
Sorghum	7.5	979	9.75	1,192	10.5	1,413	11	1,555	11.5	1,752
Millets	4.5	601	6.75	1,044	9	1,054	9	1,136	9.5	1,287
Pulses - Chickpea & Pigeonpea	6.75	1,066	8	1,236	8	1,249	8	1,324	8	1,402
Groundnut	3.5	528	5.5	872	7	937	10	1,076	10	1,139
Economics	4.75	521	5	589	5	549	5	592	5	632
Subtotal	35	4,675	42.75	6,282	50.5	6,600	55	7,367	56	8,002
b. Research Support Service Activities										
Office of the Director (Research)	1	101	1	100	1	133	1	145	1	155
Plant Quarantine	-	50	-	66	-	63	-	66	-	69
Genetic Resources Unit	2	264	2	294	2.5	360	3	408	3	432
Biochemistry	1	141	1	183	1	167	1	179	1	189
Farm Development Operations	1	527	1	676	1	717	1.5	864	2	941
Library & Documentation	-	109	-	197	-	196	-	217	-	228
Information Services	3.5	283	4	398	4	364	4	387	4	411
Computer Services & Statistics	2	191	2	231	2	227	2	245	2	260
Subtotal	10.5	1,666	11	2,145	11.5	2,227	12.5	2,511	13	2,685
Total Research Activities	45.5	6,341	53.75	8,427	62	8,887	67.5	9,878	69	10,687
2. INTERNATIONAL COOPERATION ACTIVITIES										
Office of the Director (Intl. Coop)	1.5	207	2	224	2.5	215	3	251	3.5	369
Training & Fellowships	1.5	456	1	636	1	680	2	758	2	793
Conferences & Symposia	-	195	-	213	-	184	-	191	-	198
Total	3	858	3	1,073	3.5	1,079	5	1,200	5.5	1,360

(continued on page 63)

Table 9. Continued....

	1980		1981		1982		Projections 1983		1984	
	MY	Cost	MY	Cost	MY	Cost	MY	Cost	MY	Cost
3. GENERAL ADMINISTRATION										
Board of Governors	-	72	-	102	-	98	-	102	-	106
Administration	2	734	4	861	4	948	4	1,106	4	1,237
Quinquennial Review	-	-	-	-	-	-	-	100	-	-
Total	2	806	4	963	4	1,046	4	1,308	4	1,343
4. GENERAL OPERATIONS										
Transportation										
Motor Pool	-	268	-	336	-	321	-	342	-	362
Physical Plant Services	1	702	1	861	1	805	1	863	1	915
Housing & Food Services	1	214	1	365	1	385	1	413	1	438
General Expenses	-	1,163	-	890	-	1,173	-	1,269	-	1,257
Total	2	2,347	2	2,452	2	2,684	2	2,887	2	2,972
5. ALL OTHERS										
Contingency	-	-	-	-	-	134	-	305	-	327
Provision for Future Price Changes	-	-	-	-	-	2,352	-	5,157	-	8,161
Total	-	-	-	-	-	2,486	-	5,462	-	8,488
GRAND TOTAL-CORE BUDGET	52.5	10,352	62.75	12,915	71.5	16,182	78.5	20,735	80.5	24,850
CATEGORIES OF EXPENSES										
Personnel Services		5,226		6,461		7,134		7,907		8,433
Supplies and Services		4,315		5,259		5,334		5,985		6,486
Equipment Replqcement Travel		795		958		1,023		1,084		1,135
Others: Contingency/ Future Price Changes		-		-		2,486		5,462		8,488
TOTAL		10,352		12,915		16,182		20,735		24,850

Table 10. Principal Staff positions for core research and regional activities in 1980 and projected for 1984.

	ICRISAT Center		Cooperative Program	
	1980	1984	1980	1984
Farming Systems	8	8	2	4
Sorghum	5	6	8	7
Millet	5	5	2	5
Pulses	6	6	2	2
Groundnut	5	6	1	4
Economics	3	3	2	2
Genetic Resources	2	3	-	-
Biochemistry	1	1	-	-
Farm Development Operations	1	1	-	1
Computer Services	1	1	-	-
Statistics	1	1	-	-
Administration	4	6	2	4
Training and Fellowships	2	2	-	-
Total:	44	49	19	29

Note : (a) These totals exclude the position of the Director General.
(b) Regional projects in Cooperative Programs include some positions funded by special projects.

Table 11. Requirements for Capital funds 1980-84.

	1980 $'000	1981 $'000	1982 $'000	1983 $'000	1984 $'000
1. Site development, ICRISAT Center	18.4	35	41	28	40
2. Campus external work	61.0	126	65	191	50
3. Building construction, Phase II	272.5	900	1,015	90	-
4. Other construction	-	66	72	653	200
5. Equipment	921.5	268	525	845	750
6. Others: including architect fees	210.0	120	113	75	-
7. West Africa: Capital	352.0	-	250	573	1,000
8. Contingencies (3%)	62.0	-	62	74	61
Total	1,897.4	1,515	2,143	2,529	2,101