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Cover: Runoff being measured near Anantapur in Andhra Pradesh, India, in efforts to evolve sustainable systems of agriculture.

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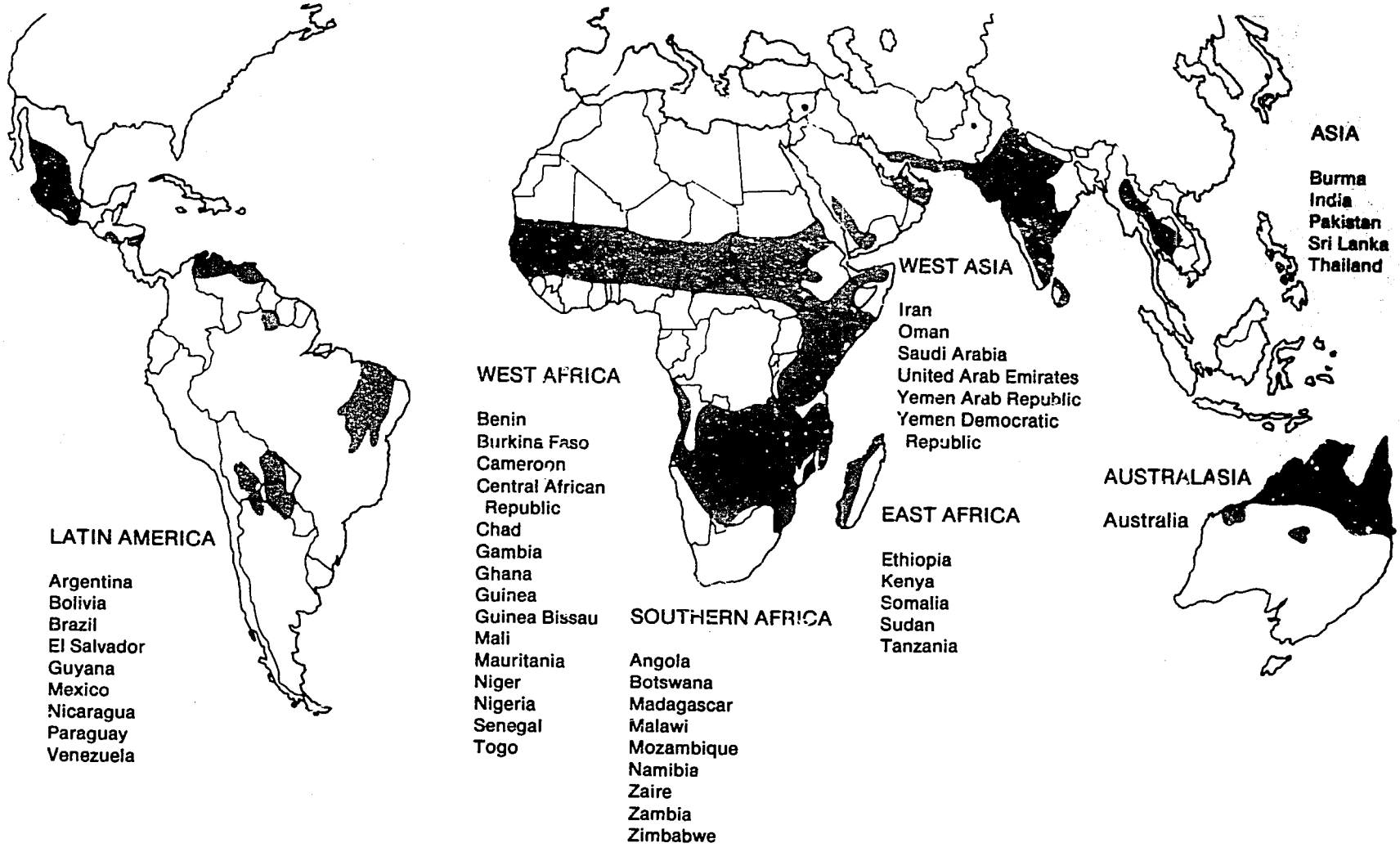


Semi-arid areas (in yellow) covered by ICRISAT's mandate. Green squares indicate location of ICRISAT Center in India and Sahelian Center in Niger; red dots indicate collaborative research stations where ICRISAT scientists have been posted.

About ICRISAT

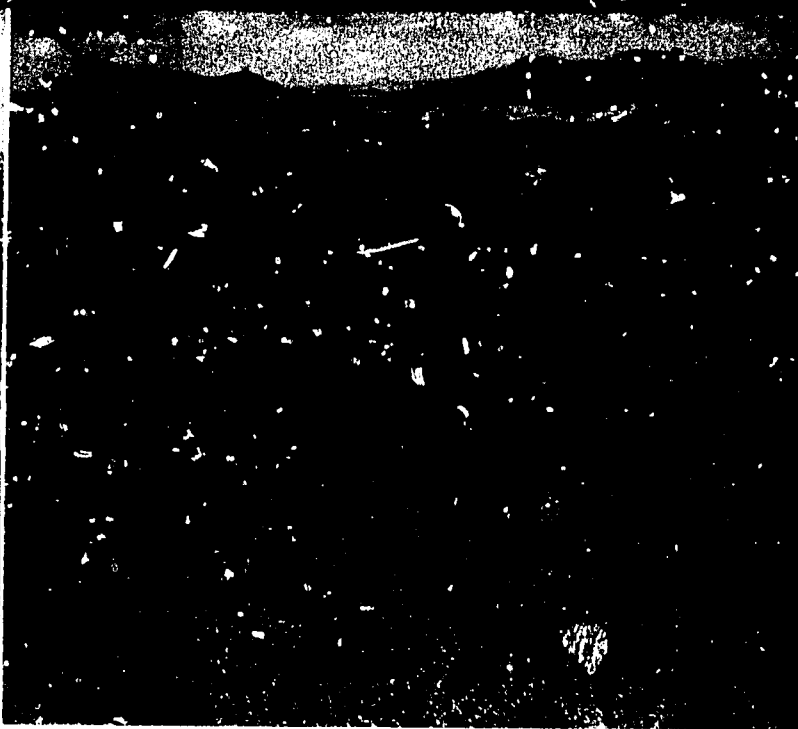
ICRISAT is one of 13 international centers in a worldwide research network devoted to improving food production in less developed countries. ICRISAT's mandate is to improve the yield, stability, and food quality of five crops basic to life in the semi-arid tropics (SAT) and to develop farming systems that will make maximum use of the human and animal resources and the limited rainfall of the region.

The seasonally dry semi-arid tropics are spread over nearly 20 million square kilometers and cover all or parts of 50 nations on five continents. They include much of South Asia, parts of Southeast Asia, West Asia, and Australia, two wide belts of Africa, areas of South America and Central America, and much of Mexico.

The SAT is a harsh region of limited, erratic rainfall and nutrient-poor soils. It is populated by more than 700 million people, most of whom live at subsistence levels and depend for their food on the limited production of small farms.

The crops researched by ICRISAT are sorghum and pearl millet—two of the major cereals in the SAT—and chickpea, pigeonpea, and groundnut, the most important food legumes of the region. Groundnut, rich in oil, is also an important cash crop for the SAT farmer. The four others are all primarily subsistence food crops; over half the total production of each—in some places nearly all of it—is consumed on the farms where it is grown. ICRISAT's headquarters are at Patancheru, India, 26 km northwest of Hyderabad, but it also has scientific staff posted in six countries of Africa, in Mexico, Pakistan, and Syria, and at five cooperative research stations of agricultural universities in India. Principal operations in Africa are in Burkina Faso, Kenya, Malawi, Mali, Niger, Sudan, and Zimbabwe. Scientists were previously posted also in Nigeria and Senegal, but funding for these positions has ceased. The search is on for a suitable site to locate a West Africa regional program for sorghum.

The two main bases for ICRISAT's work in Africa are at the Sahelian Center near Niamey, Niger, and the SADCC/ICRISAT sorghum and millets improvement program at Matopos, near Bulawayo, Zimbabwe, set up in response to an invitation from the nine-nation Southern African Development Coordination Conference (SADCC).



Some of the agronomic impact already visible from ICRISAT's research (clockwise, from top left): Sorghum hybrid ICSH 153 (also called SPH 221), released for rainy-season cropping in India, seen growing on a farmer's field near Davanagere, Karnataka. Chickpea K 850 × F 378, growing at the Debre Zeit experiment station in Ethiopia, was one of the two ICRISAT chickpeas to be released in that country. A farmer in Nizamabad, Andhra Pradesh, stands amid his crop of ICGS 11, a groundnut released in India for postrainy, irrigated cultivation. ICRISAT pigeonpea ICPL 151, growing near Gwalior, India; it is nearing release to farmers in India and its seed has also been provided on request to the Government of Suriname for a pilot project there.

Introduction

ICRISAT made important progress in 1986 on the many facets of its mandate.

Nine more ICRISAT finished products reached farmers' fields this year, adding to the many already released in previous years in several countries of the world. Yet others reached advanced stages of prerelease testing. In addition, improved breeding materials from ICRISAT were being used in national programs. Taken together, these represent a substantial payoff for research already done.

Basic and strategic research was intensified on both crop improvement and resource management. Some successes were achieved in building and using a reliable base of knowledge on the resources available to farmers in the semi-arid tropics, so that sustainable systems of agriculture can be evolved. New sources of genetic diversity were identified and utilized. Research moved forward on overcoming diseases, insect pests, and drought, and on improving grain quality and nutrition. Some of the improvements involved use of wild species, a promising avenue for further research.

Training received added impetus. While the range of disciplines and levels covered in training activities at ICRISAT Center and elsewhere was wide, plans moved forward for establishing an organized training program at the ICRISAT Sahelian Center for the West Africa region.

Network activities were strengthened in West, southern, and eastern Africa, and in Asia, where an Asian Grain Legumes Network was initiated. These activities will ensure a coordinated approach to improving food production in priority areas of the semi-arid tropics.

Progress on all these aspects is outlined on the following pages and described in greater detail in the 1986 ICRISAT Annual Report.

L.D. Swindale
Director General

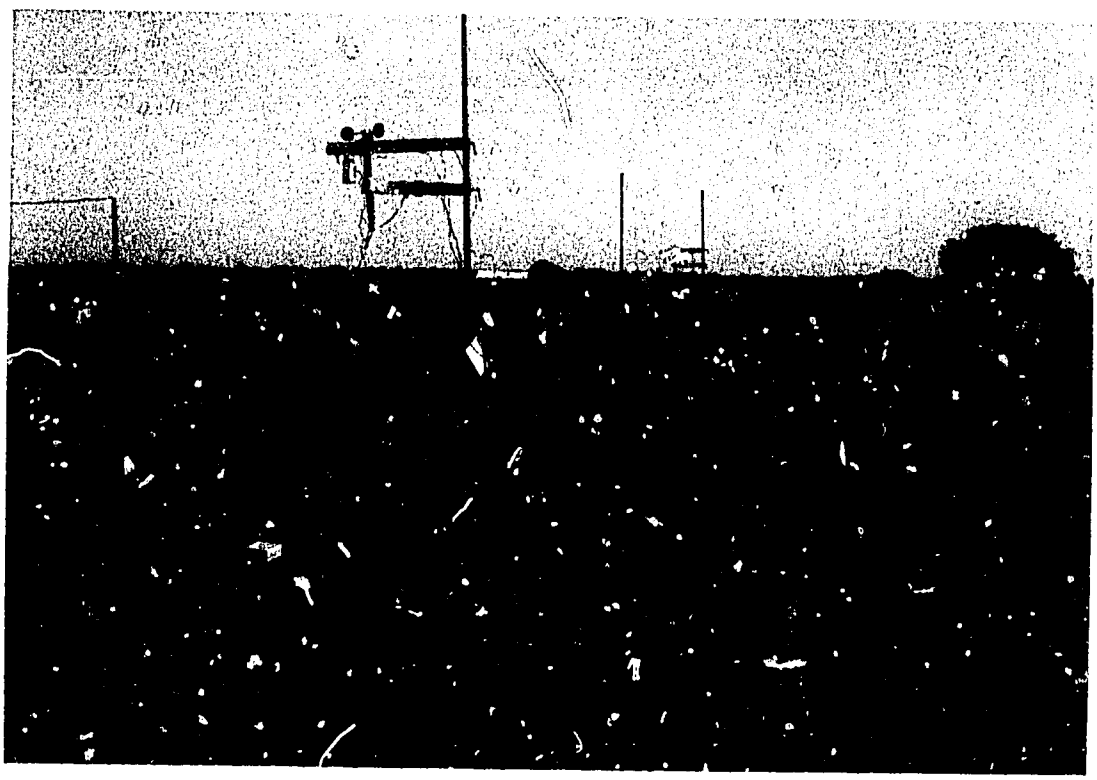
Improving Management of Resources

Farming in the semi-arid tropics is a difficult task in most seasons. The natural resources available to the subsistence farmer are meager. To improve his ability to cope with a harsh environment, he requires planning and skills that stretch beyond methods already tested and proven in better-endowed environments.

A reliable base of knowledge needs to be built up, so that a planned and concerted effort can be mounted to stabilize or increase crop production in areas that have not traditionally been the concern of commercial farmers and crop researchers.

The work has many facets. Initially it involves collecting soil and climatic data and analyzing them to assess the potential for crop yield in different regions; studying soil fertility and the means to improve it with locally available materials, where possible; and evolving practices for land management and tillage, which conserve water and mini-

Measuring microclimate over a groundnut crop. Records are then pooled and analyzed to assess the potential for crop yields.



mize the loss of soil by erosion.

The next step is studying cropping systems, both traditional and innovative, to understand how plants interact with each other and with their environment. This includes selecting sowing dates and populations to achieve optimum crop yields, identifying species that coexist successfully in intercrops, and introducing trees suitable for agroforestry systems.

To reach a better understanding of the economic and social restraints on cropping systems, information is gathered and analyzed about the adoption of new technology, farm and family size and income, labor availability, the distribution of property and social interactions, market infrastructure, and subsidies and incentives.

As part of an international effort across that wide range of disciplines, ICRISAT is attempting to improve the management of natural and human resources in the semi-arid tropics. Agroclimatologists, soil and water scientists, computer programmers and analysts, economists, agronomists, physiologists, pathologists, and breeders pool their resources to search for solutions that often seem years, if not decades, away.

Progress in any one year or a few years may seem meager, given that wide mandate. The efforts reported here represent a further step toward the long-term goal of increasing food supplies in the semi-arid tropics within systems that can be sustained.

We report here a few successes, acknowledging that much effort still lies ahead.

The characterization of soils and rainfall potential is a key element in improving the management of resources. ICRISAT scientists have already divided the semi-arid tropics of India according to four soil types in three rainfall zones. They also classified each zone in terms of population, area, and importance of ICRISAT mandate crops. This provided an index for setting research priorities for each of the crops.

A similar soil-climatic zonation, now completed for West Africa, delineates soil types and growing seasons for 160 locations. The length of growing seasons was determined from monthly rainfall and the normal beginning and ending of rains recorded at local weather stations. Growing seasons of 60 to 100 days were estimated for the Southern Sahelian Zone, which includes the ICRISAT Sahelian Center (ISC) in Niger; 100 to 150 days for the Sudanian Zone; and 150 to 210 days for the Northern Guinean Zone.

Dry spell lengths at 90% probability were computed for Niamey, Niger (mean annual rainfall 560 mm), Kaolack, Senegal (800 mm), Ouagadougou, Burkina Faso (830 mm), and Sikasso, Mali (1300 mm). The analysis was based on computations for each year of recorded rainfall, and it can be used as a guide for breeding varieties with the appropriate maturity duration for each location.

Growing-season lengths were also computed for early, normal, and delayed onset of rains. This information will be useful in deciding whether to plant cultivars* that mature early, medium, or late, depending on the length of the growing season, estimated from when the rains start. At Niamey, for example, rains normally begin 12 June. If the onset of rains is 20 days earlier, there is a 43% probability that the growing season will exceed 115 days. This estimate would permit using late-maturing cultivars. On the other hand, when the rains are delayed until the end of June, there is only a 2% probability that the growing season will exceed the mean length of 95 days, and it would be safer to plant early-maturing cultivars.

Such a management strategy makes full use of the limited rainfall and agricultural resources available in West Africa. It was found, for instance, that the early onset of rains (23 May) at Niamey in 1986 permitted a second crop of early-maturing cowpea to be grown, after a crop of pearl millet had been harvested. A bonus yield of cowpea hay resulted, showing that the strategy could be applied.

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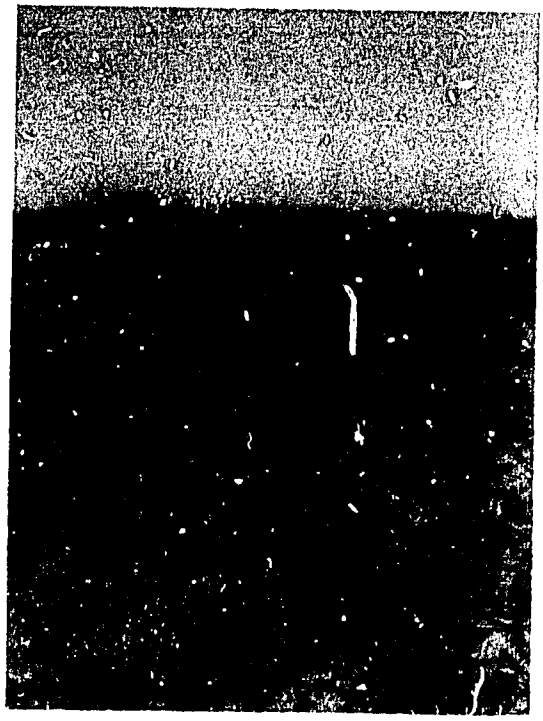
* cultivated varieties or hybrids.



A crop of cowpea hay was obtained after harvesting pearl millet at the ICRISAT Sahelian Center in 1986, when rains arrived early and supported a second crop.

In India, a soil-climatic analysis was completed this year to measure the period when water is available at 230 locations. A computer program was developed to identify locations with similar periods of water availability, so that suitable technologies can be identified.

Along with the collection and analysis of soil and climatic data, efforts are being made to simulate soil and crop behavior, using computer models.

Runoff during intense rains, resulting in soil erosion, is a major problem in crop production in the semi-arid tropics. ICRISAT has developed a model to predict runoff from rainfall under various conditions and tested it at ICRISAT Center since 1982. The model has also been tested under cropped conditions at Madhya Pradesh, India, in a high-rainfall area (1250 mm per year). It fairly accurately predicted the annual runoff and seems acceptable for predictions that involve long periods. However, its weekly and daily predictions were not reliable.

In experiments at ICRISAT Center over the past 2 years, the application of phosphogypsum at 10 tonnes per hectare significantly increased the water infiltration rate and reduced runoff on Vertisols, the deep black soils which have good water-retention capacity. With the phosphogypsum treatment, the average grain yield of maize on these soils was 4 tonnes per hectare in both years, compared with 3.5 tonnes per hectare without the treatment. Subsequent yields of chickpea, grown as a sequential crop, were not affected by this treatment.

Once weather, soil, and crop data are available for given locations, models can imitate the processes of crop growth. From these models, it is possible to assess crops for a given location or type of season, dates for sowing and for applying irrigation (if required), optimum fertilizer levels, and yields obtainable under stress. Such information can be—and has been—used to aid crop planning decisions, especially where limited resources need to be allocated to priority needs. Following the success of a sorghum model developed along these lines, groundnut modeling is now being attempted, based on data from seven locations in India and one in Thailand. This work is done in collaboration with IBSNAT (The International Benchmark Sites Network for Agrotechnology Transfer) and draws upon a model already developed at the University of Florida, USA.

Obtaining higher crop yields from nutrient-poor soils, through both chemical and biological means, is another important aspect of resource management research. In continuing soil-fertility studies at the ISC this year, applied phosphorus (P_2O_5), in doses as small as 30 kg per hectare, tripled millet yields. The residual effects of phosphorus applied 2 years ago, at 60 kg per hectare, were still significant: millet yield in previously treated plots was 700 kg per hectare this

Based on groundnut experiments like this at several locations, data were obtained to begin work on modeling that crop. Such models imitate the processes of crop growth and can be used to aid crop planning decisions.

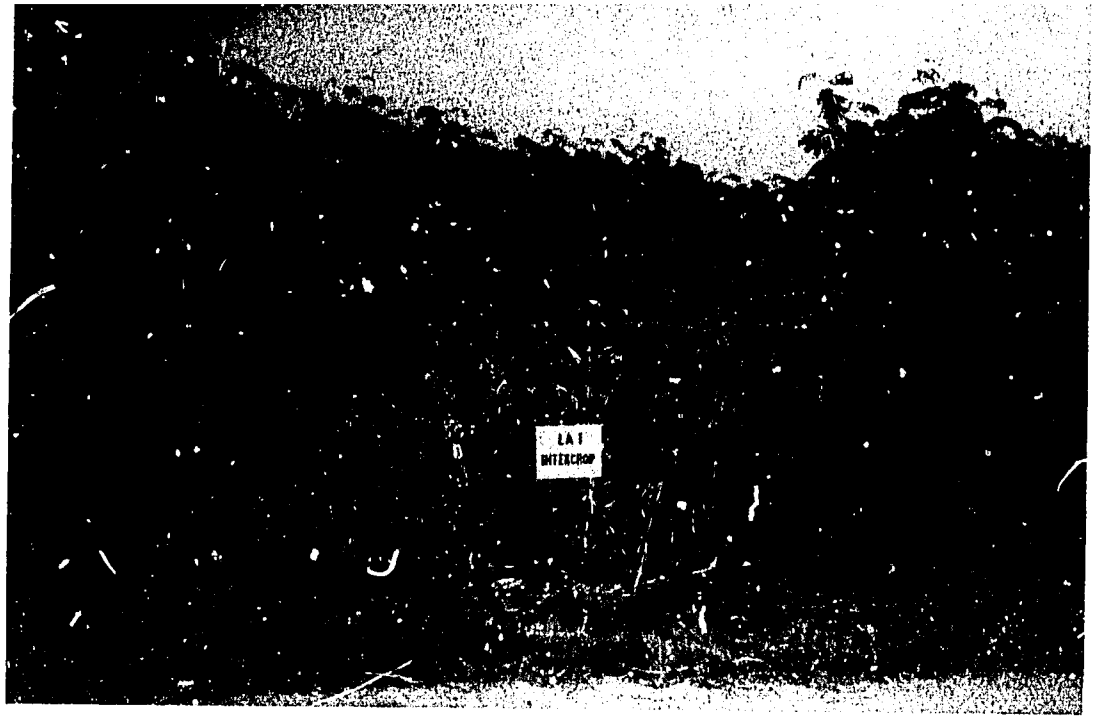
year, compared with 200 kg in nontreated plots.

Also at the ISC, continuing studies with the International Fertilizer Development Center confirmed the efficiency of partially acidulated rock phosphate in meeting the requirements of millet crops. As the product can be made from locally available rock with the help of a processing plant—and more cheaply than commercial fertilizers—substantial savings in foreign exchange for Niger can result from this finding.

Agroforestry is a relatively new subject of research at ICRISAT and is applicable to resources management work in both India and Africa.

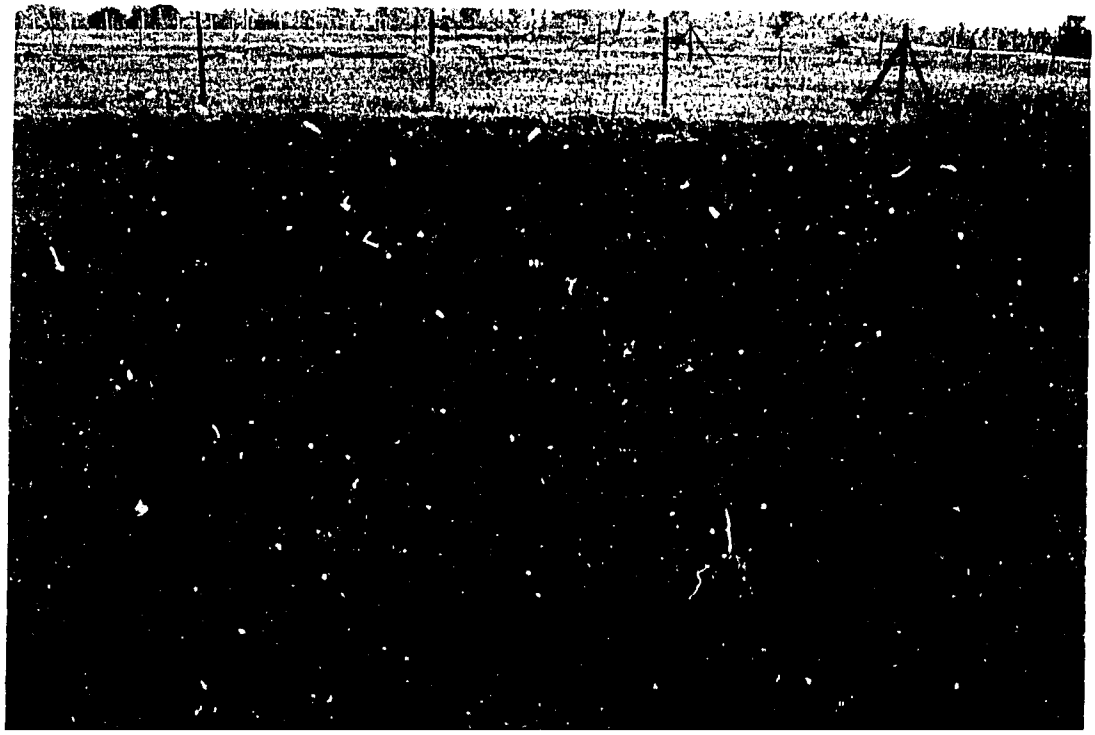
A 2-year study, funded by the Ford Foundation, looked at the biological and economic potential of agroforestry in increasing the productivity of farming systems in the semi-arid tropics. Planting trees can supplement existing sources of fodder and fuelwood, and it can confer environmental benefits by reducing soil erosion and wind damage to crops (especially in sandy areas). But its adoption takes several forms and is constrained by many factors. Speedy adoption of some forms could widen the income disparities prevailing in rural India, ICRISAT economists found.

Related experiments by India's Central Research Institute for Dryland Agriculture indicated that trees compete strongly with crops for water, and methods to decrease this competition need to be explored. Options include wide spacing between rows (10-20 meters) and using drought-tolerant species and varieties.



An agroforestry experiment at ICRISAT Center, with millet growing between rows of leucaena. This work and related experiments by India's Central Research Institute for Dryland Agriculture indicated that the competition for water between trees and crops needs to be reduced.

Two groundnut varieties doing well in an experimental rice-based cropping system in India. The study is being carried out jointly with the Indian Council of Agricultural Research.



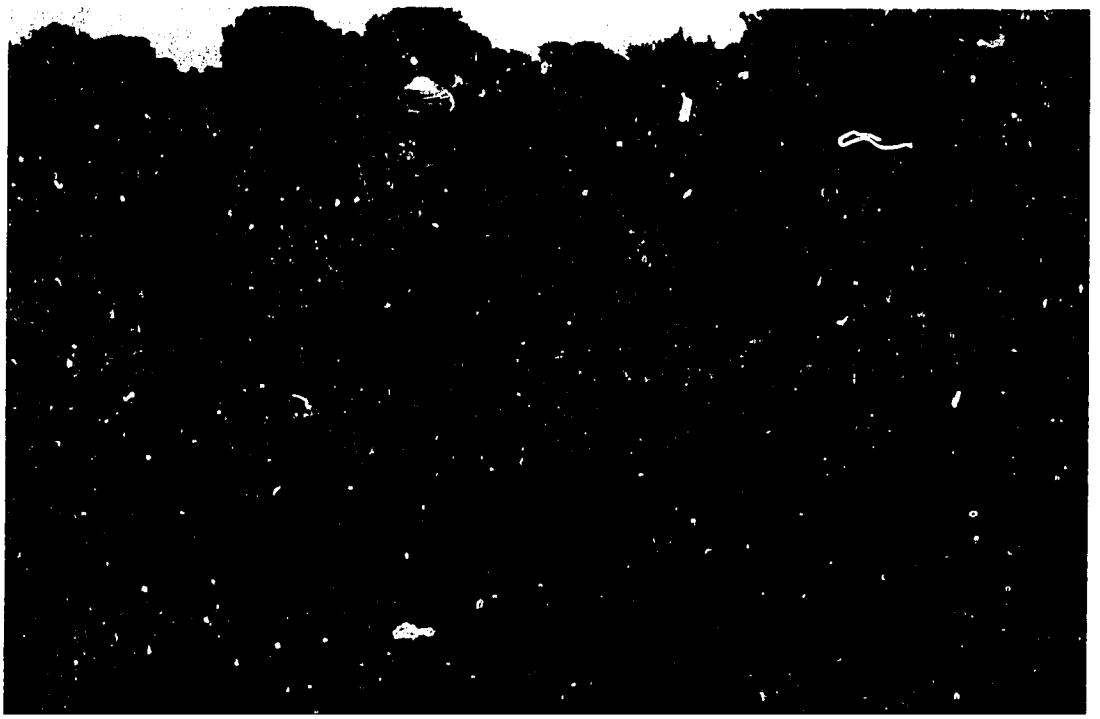
In a rice-based cropping systems study in India, conducted jointly with the Indian Council of Agricultural Research, groundnut and sorghum were found the most suitable crops after rice. Yields of 3 to 4 tonnes per hectare of sorghum grain and 1 to 3 tonnes per hectare of groundnut were obtained.

Other studies by ICRISAT economists also aimed at identifying and evaluating factors that aid or constrain the positive impact of technology. One such followed up the use by farmers of hand-held, ultra-low-volume (ULV) insecticide sprayers to protect their pigeonpea crops in the Indian village of Farhatabad near Gulbarga, Karnataka.

Since a study in that village 4 years earlier, the use of ULV sprayers had increased from 2 to 100 farmers, but most of them took only rudimentary precautions to safeguard their health. Because many farmers could not read information on spraying precautions or used the sprayer for the first time, some 70 cases of monocrotophos poisoning resulted during 1984-85. ICRISAT engineers are devising corrective steps. Based on measurements of droplets falling on operators and of wind speeds at which spraying is safe, the engineers are designing plastic shields to prevent droplets from reaching the operator's body or clothing.

Another economics study showed that farm size in semi-arid India is steadily declining. Across 300 cultivator households in 10 study villages, the average size of holding has decreased since 1950 from about 5 to 3 hectares. Declining farm size means more farmers and field boundaries, adding to the complexity of using a watershed as the land base in technology generation and transfer. ICRISAT's strategy for improved farming of black soils thus has to be increasingly based on the willingness of cooperating farmers to identify watersheds and adjust their field boundaries.

A farmer in Chevella village, Andhra Pradesh, India, uses the ultra-low-volume sprayer with essential protective clothing. Farmers in another Indian village suffered when they did not observe suggested precautions, and ICRISAT engineers are designing improvements in the sprayers to help protect such farmers.



In policy-oriented research by ICRISAT economists, a survey of 80 Indian villages suggested that government efforts to distribute common land among the poor have failed to produce the benefits intended. Infrastructural support was inadequate, and the land too marginal to sustain productive enterprises.

Through that seeming maze of interdisciplinary research, the findings that have emerged—and will continue to emerge—point to new ways of improving the management of agricultural resources in an environment where options are at present severely limited.

■

Augmenting Genetic Resources

ICRISAT's gene bank grows richer each year with the addition of new plant resources collected from around the world. In some of these accessions is the potential to resist diseases and pests that damage or destroy crops, and to vastly increase the nutritive value and yield of their grain. It is the task of the scientists to discover that potential and use it in improving crops for the benefit of farmers and the people they feed throughout the world.

This year 3418 new accessions of sorghum, pearl millet, groundnut, chickpea, pigeonpea and minor millets from 29 countries were added to the resources conserved in the cold storage vaults of the ICRISAT gene bank. They brought the total accessions to 89 117 from 126 countries.

Although the diversity present in these samples is great and their number appears large, the collection is considered small in relation to the worldwide genetic diversity not yet assembled and conserved. Further samples will be collected over coming years, in cooperation with governments of the countries where they are located, and they will be maintained and conserved in cold-storage facilities at ICRISAT and other repositories designated by the International Board for Plant Genetic Resources and national governments. (ICRISAT serves as world repository for the genetic resources of its five mandate crops and for the six minor millets commonly known as proso, finger, foxtail, little, barnyard, and kodo millets.)

A concerted effort is made in germplasm collection expeditions to salvage important vanishing landraces of all these crops and to capture new and desirable genetic traits, including those in wild species, for use in present and future crop improvement programs. Among the new accessions added this year were primitive sorghums cultivated by tribal people in the Indian states of Orissa, Bihar, and Madhya Pradesh, cultivated and wild relatives of pearl millet from India and Cameroon, representative landraces of pigeonpea from Jamaica, Guyana, and Venezuela, and landraces of groundnut from Mali.

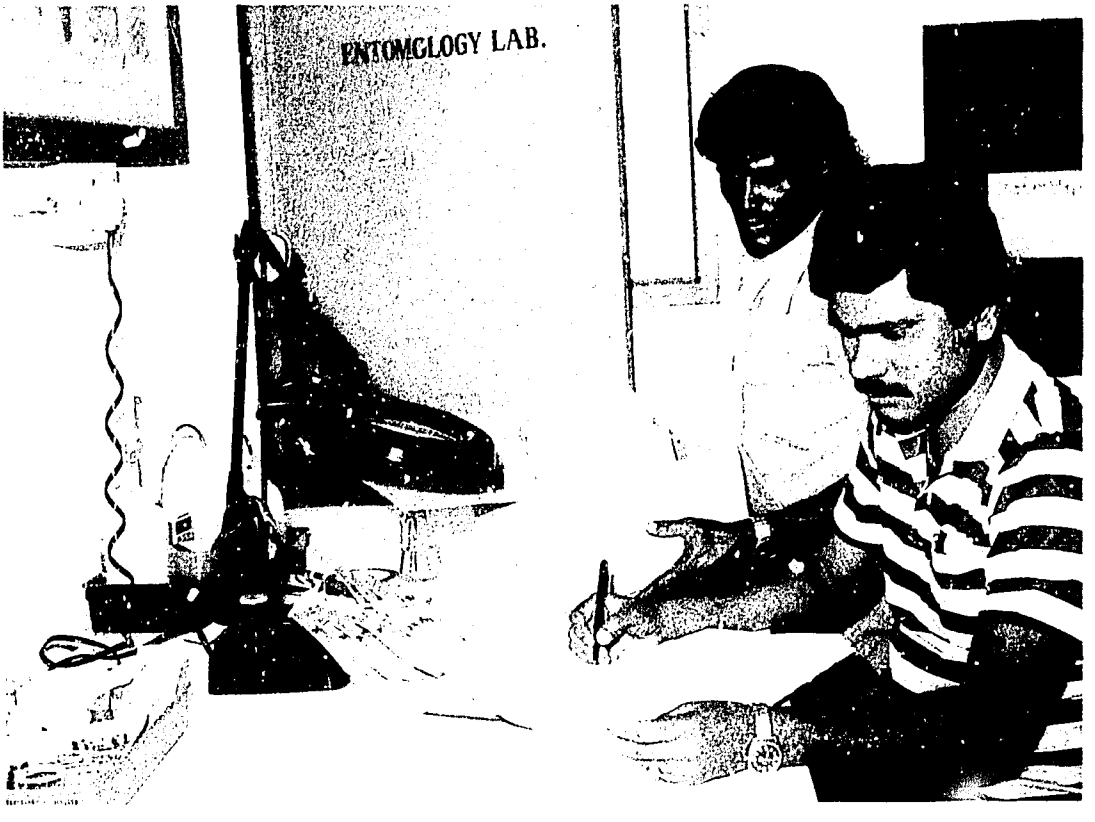
ICRISAT makes the resources of its gene bank freely available, on request, to plant scientists throughout the world. This year it supplied 24 298 seed samples to scientists in India and 16 497 to those in 58 other countries, besides providing 38 064 samples to its own scientists for their crop improvement work.

Once germplasm has been collected, it must be characterized and evaluated, monitored during storage, and rejuvenated periodically through replanting to be kept viable.

Evaluation is the key to identifying genetic

Finger millet sample being collected from the threshing floor in Orissa, India.

Seed materials being registered for export. Over 16000 samples were sent to scientists in 58 countries during 1986. Even larger supplies were made to scientists in India and within ICRISAT.



traits and effectively using germplasm. In the past, this work has been done mostly at ICRISAT Center—often far from the originating area of the germplasm—by the Institute's Genetic Resources Unit and crop improvement scientists. Increasingly, ICRISAT is now turning to national programs for assistance in evaluating the germplasm in areas closer to its origin, where it is well adapted. Such collaborative efforts were initiated this year with national research organizations in Ethiopia, Kenya, and Zimbabwe—and with good results.

In India, joint evaluations were carried out at various locations—and for the first time—with the National Bureau of Plant Genetic Resources (NBPGR). Under the program, 12 681 accessions of ICRISAT's five mandate crops were characterized.

This included evaluation of 2000 pearl millet accessions for drought tolerance at the NBPGR's regional station in Jodhpur, where rainfall was less than 200 mm this crop season. More than 80 accessions with possible drought tolerance have been identified for use in crop improvement.

A total of 2000 pearl millet accessions were sent to Bulawayo, Zimbabwe, for joint evaluation with the SADCC/ICRISAT regional cereals improvement program. After the evaluation, 9 accessions have been selected for inclusion in a pearl millet late-variety trial. A further 96 were selected for grain, 49 for fodder, and 11 for both traits.

ICRISAT also collaborated with the National Dryland Farming Research Station in Kenya to evaluate 500 vegetable-type pigeonpea accessions at Machakos and Kiboko,

Pearl millet accessions being evaluated at Jodhpur, India, jointly with the National Bureau of Plant Genetic Resources.

This dwarf pigeonpea, selected for its earliness and vegetable traits in Kenya, is being used in national breeding efforts there.

Pods on plant of ICC 4854, a line sent from Mexico to the Indian program and conserved later at ICRISAT Center, appear promising in evaluation in Ethiopia.

This wild species of pearl millet, Pennisetum violaceum, *collected by the ORSTOM team located at the ICRISAT Sahelian Center, is being studied for possible* Striga *resistance.*

In germplasm evaluation activities during 1986:

- Four accessions of wild sorghums were identified with high resistance levels to shoot fly.
- Two new dwarfing genes were identified in pearl millet.
- Five chickpea accessions from Ethiopia were found superior to the commonly grown cultivar, Annigeri.
- Several vegetable-type pigeonpea accessions with earliness were identified for eastern Africa.

resulting in the identification of several short-duration types with other desirable traits. In Ethiopia, ICRISAT collaborated with the Plant Genetic Resources Centre and the Alemaya University of Agriculture to evaluate 1033 chickpea accessions at the Debre Zeit Research Station, resulting in the identification of several accessions with superior agronomic traits.

A collaborative project at the ICRISAT Sahelian Center with two geneticists of ORSTOM, the French Institute of Scientific Research for Development through Cooperation, explores wild relatives of pearl millet. Two collecting expeditions in Burkina Faso, Mali, and Niger have yielded 81 accessions of *Pennisetum violaceum*, and seeds of these are now stored at ICRISAT Center and with ORSTOM in France. The morphology and flowering behavior of these accessions are being studied, and their possible resistance to a parasitic weed, *Striga hermonthica*, is being investigated. The ORSTOM team is also breeding male-sterile lines based on *P. violaceum*, to diversify the available material. ■

Developing Disease Resistance

A vital contribution that ICRISAT makes to stabilize agricultural production is in improving the plants' ability to resist diseases that destroy them or drastically reduce their yields of grain and fodder.

Pathologists work closely with breeders and other scientists on interdisciplinary teams to identify disease-resistant genes in wild species and cultivated plants, and to incorporate those traits into lines with other desirable traits, such as high yield or tolerance to drought and other stresses. The process requires years of patient and persistent work, as plants are screened in nurseries under high disease pressure and the best of them are then crossbred with lines that show other desirable traits.

ICRISAT has made considerable progress over the past 13 years in developing cultivars resistant to many of the diseases that plague its five mandate crops, and has made this material available to breeders in national programs for adaptation to their areas and release to farmers. But some major problems remain to be overcome. One such is aflatoxin contamination in groundnut.

Aflatoxin is a poisonous substance that causes cancer in humans. It has contaminated agricultural crops through the ages and is found in stored grain, especially groundnut. It is produced by the fungi *Aspergillus flavus* and *Aspergillus parasiticus*.

ICRISAT has identified several groundnut genotypes that have conclusively demon-

Examining and scoring groundnut seed samples for invasion by the fungus that causes aflatoxin. Inset shows varying levels of contamination among lines tested.

strated resistance to preharvest seed invasion by *Aspergillus flavus*. Three of these genotypes, AH 7223, J 11, and UF 71513, also have resistance to invasion and colonization by *A. flavus* of stored seed of groundnut.

In continuing work on the aflatoxin problem, ICRISAT scientists made 529 selections this year from crosses between *A. flavus*-resistant and adapted lines, based on pod yield, pod shape, and other agronomic traits. Stored seeds from these selections will be evaluated in the laboratory for resistance to invasion by *A. flavus*.

In continuing evaluation of 200 breeding lines selected in 1985, five lines showed levels of seed colonization by *A. flavus* comparable with those of the resistant lines J 11 and UF 71513, although their yields were reduced because of drought.

The effects of drought stress on preharvest seed invasion by *A. flavus* were examined for the second year in a field trial at ICRISAT Center. Eight groundnut genotypes were used, four with resistance to colonization of stored, mature seeds by *A. flavus* in laboratory inoculation tests and four susceptible genotypes. Late-season drought stress (95 to 125 days after sowing) significantly increased infection by *A. flavus* in seeds of all eight genotypes tested. Levels of infection were about the same as those recorded in the postrainy season last year.

Overcoming the aflatoxin problem holds a high priority in ICRISAT's research plans. Further studies will be made on the interaction between drought, soil temperature, and the invasion of groundnut pods by *A. flavus* and *A. parasiticus*, and cultivars with resis-

Soil solarization was confirmed as an effective tool in disease management of legume crops. At rear is pigeonpea grown on solarized soil; in front, patchy growth on a nonsolarized plot

tance to those fungi will be evaluated in different environments by regional and national programs.

A new tool in improving disease management in legume crops is soil solarization, which increases temperatures by as much as 10°C when moist soil is covered with transparent polythene sheets in hot weather. This technique produced dramatic effects in experiments at ICRISAT Center for the second year in succession. It drastically reduced the populations of fusarium wilt pathogens and parasitic nematodes in the soil, and it enhanced the growth of both wilt-resistant and wilt-susceptible cultivars of pigeonpea and chickpea.

An important offshoot of this research was the isolation from the solarized soil of an organism that is hostile to wilt pathogens in both chickpea and pigeonpea. The organism was identified as *Penicillium pinophilum* by the Commonwealth Mycological Institute in the UK. It was relatively abundant in the soil.

The effect of soil solarization was also tested on peanut clump virus, an important disease of groundnut, by covering wet, infested soils with plastic sheets in March and April. Incidence of the disease was considerably lower than in nontreated plots.

The solarization experiments will continue next year, and they will be extended to locations outside ICRISAT Center.

Another important development was identification and study by ICRISAT scientists of a previously undescribed form of downy mildew resistance in pearl millet, one in which plants outgrow the disease and may even become immune to it. The recovery trait was found in 28 of 33 genotypes studied this year and was expressed at all three locations in India where it was tested. It was also observed in Mali and Niger.

Recovery of infected plants was expressed in two ways: (1) in main shoots, where symptom-free new leaves and panicles formed after one or more early-formed leaves showed downy mildew symptoms; and (2) in secondary shoots, where symptom-free basal shoots arose from plants showing downy mildew symptoms on the main shoot. Nor-

mally, once a plant shows downy mildew symptoms, all leaves and panicles subsequently formed are diseased.

Formation of downy mildew spores was generally reduced in infected tissues of plants that recovered, compared to infected tissues of plants that did not recover. Following recovery, new infection symptoms rarely developed, even when spores were injected or plants were cut back to encourage fresh tillering. The recovery trait appears to be heritable.

In other disease-oriented research:

- An ICRISAT millet variety with excellent resistance to smut and downy mildew, ICMV 82132, performed well in yield trials in both Zambia and India.
- In Burkina Faso, two ICRISAT pearl millet varieties proved totally resistant to downy mildew and 11 were classified as highly resistant to the disease in screening by pathologists of the national program.

Recovery from downy mildew in pearl millet: basal leaves are infected, but leaves formed later are healthy.

- Two sorghum lines, IS 7775 and IS 18688, were found resistant to all nine confirmed isolates of the fungus that causes anthracnose disease. They were among 249 lines screened in an experiment to study variability of the pathogen. At Pantnagar in northern India, three sorghum germplasm accessions and 29 breeding lines continued to show high levels of resistance to anthracnose after 4 to 5 years of screening.
- Grain mold resistance in colored grain sorghum was found to be heritable and can be successfully transferred to cultivars with white grains, good grain quality, and high nutritional value.
- Researchers learned that head bug damage predisposes sorghum to grain mold infection. Even mold-resistant genotypes became susceptible to mold after head bugs infest their panicles. This finding can be important in future experiments aimed at developing mold resistance in sorghum.
- ICPL 227, one of four ICRISAT pigeonpea lines resistant to both fusarium wilt and sterility mosaic diseases, was entered in All India Coordinated trials for further evaluation.
- In international trials of pigeonpea lines selected for resistance to fusarium wilt at ICRISAT Center, ICP 9145 proved resistant to wilt in Kenya and Malawi. Another line, ICP 10960, was also resistant in Kenya and five others were resistant in Malawi, where ICP 9145 is being tested on farms.
- In collaboration with the Andhra Pradesh Agricultural University in India, ICRISAT scientists screened 1616 groundnut germplasm accessions and breeding lines for resistance to the nematode disease caused by *Tylenchorhynchus brevilineatus*. The trials were held in a farmer's field near Tirupati, India, in the 1985 and 1986 rainy seasons and the 1985/86 postrainy season. Fourteen of the lines were resistant in all three seasons.

Large-scale screening of groundnut in Malawi against the rosette virus disease.

- A specially developed technique for screening groundnut lines for resistance to the rosette virus disease was confirmed as excellent in further work by ICRISAT's regional team in Malawi. In addition to ICRISAT pathologists at the Center and in Malawi, research on rosette involves the collaboration of institutions in Nigeria, Scotland, USA, and West Germany.

■

Controlling Insect Damage

The pod borer, *Heliothis armigera*, is a major pest of both chickpea and pigeonpea in the semi-arid tropics. It causes crop losses worth millions of dollars each year in India alone.

For several years, ICRISAT has had chickpea and pigeonpea lines that were resistant to the pod borer, but they have been susceptible to fusarium wilt, a major disease of the two pulse crops. This year, scientists were able to select chickpea and pigeonpea lines from crosses between *H. armigera*-resistant and wilt-resistant parents, which showed resistance to both the insect and the disease. This could be a major step forward in reducing crop losses from those two constraints.

Meanwhile, spraying with insecticides remains the best method of pod borer control. In most years, two sprays of endosulfan have

been sufficient to give adequate protection against the pod borer. As the cost of each spray is roughly equivalent to the sale value of 45 kg of chickpea, insecticide use is a good investment in years when the crop potential exceeds 1 tonne per hectare. But a caution is raised against using DDT. A study by an ICRISAT collaborator, the Tropical Development Research Institute in London, showed that *H. armigera* larvae collected from ICRISAT Center had a 70-fold resistance to DDT over the control.

For several years, ICRISAT entomologists have recorded insect damage in up to 25% of the nodules on chickpea roots. The extent of damage has varied from year to year and from location to location. This year, entomologists succeeded in collecting samples of the small fly responsible for most of the damage. It was identified as a new species of *Metopina* by a specialist at Cambridge University, UK. Still to be assessed is the impact of the insect damage on the nitrogen-fixing ability of affected chickpea.

Spodoptera litura, commonly known as tobacco caterpillar, defoliates groundnut crops throughout Asia. It is therefore a major target of entomology research in the ICRISAT groundnut improvement program. A few genotypes with resistance to *Spodoptera litura* have now been identified, offering hope that ultimately cultivars with resistance to this insect will be bred and released. An effort has also been mounted to collect information on the effects of this pest on groundnut yields, so that rational control methods can be devised.

Resistance was also found this year to *Aphis craccivora*, a transmitter of several virus diseases of groundnut. After screening

Laboratory rearing of Heliothis *pod borer larvae. This work helps multiply parasites that can reduce damage from this insect on chickpea and pigeonpea.*

6000 genotypes for resistance to this aphid, scientists found that the line ICG 5240 has an antibiotic element that suppresses development of aphid populations. In screenhouse conditions, the adult insects survived nearly twice as long on susceptible cultivar TMV 2 as on ICG 5240. Their reproductive rate was only 25 to 30% of that on TMV 2.

Effective control of sorghum shoot fly was obtained by foliar application of the synthetic compound cypermethrin, using an electrodyne sprayer. The compound was applied three times, starting at 6 days after crop emergence and repeated at 12 and 18 days after emergence. It resulted in only 5 to 8% deadhearts, compared with 60% deadhearts for sorghum plants in the nontreated control plot and 62% for those where carbofuran was applied to soil in the furrows at sowing.

Cypermethrin was also applied with ultra-low-volume and knapsack sprayers as part of the experiment, but was effective only with the electrodyne sprayer and only when the application at 6 days after crop emergence was included.

Observing larvae of stem borers reared in controlled laboratory conditions. This new facility helps speed up screening and selection of resistant lines.

The tobacco caterpillar defoliates groundnut crops and causes extensive damage. Genotypes with resistance to this insect have been identified.

Entomologists also continued efforts to determine the factors associated with stem borer resistance in sorghum. They found early panicle initiation, faster internode elongation, and the attachment position of the basal leaf to the stem were all associated with resistant lines. This finding will allow more rapid screening of germplasm lines for stem borer tolerance.

A new and modern insect-rearing laboratory installed at ICRISAT Center this year will give scientists and technicians the facilities they need for optimum and uniform levels of insect infestation in screening and selecting cultivars. They can prepare artificial diets, control the environment, and provide the sanitary conditions needed for their work. The sorghum stem borer and other insects

can be mass produced there. The laboratory is expected to greatly facilitate the screening and selection process of large quantities of germplasm and breeding materials.

Two developments in Indian national groundnut trials have confirmed the efficacy of ICRISAT materials. Genotype ICG 2271, which resists several pests and bud necrosis disease, was advanced to elite trials in a region where pest problems are serious. Over 3 years of testing, it has averaged 49% higher yields than the control. Two genotypes identified for resistance to the leaf miner, *Aproaerema modicella*, have been recommended for use as parents in the national breeding program. ■

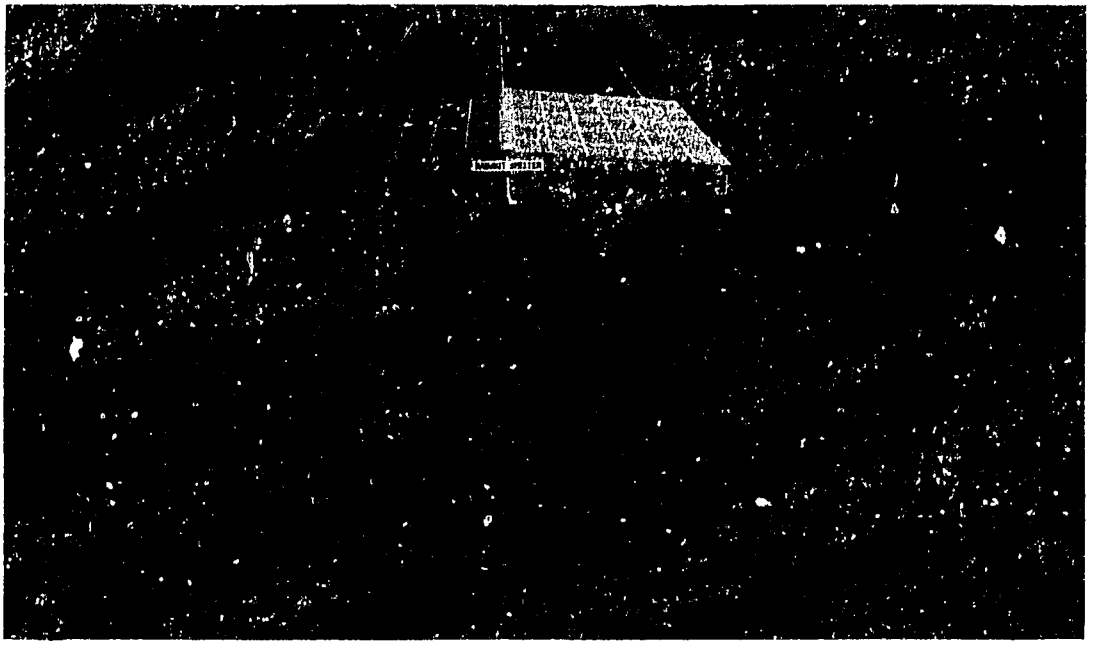
Coping with Physical Stresses

Limited and erratic rainfall is a major handicap faced by farmers in the semi-arid tropics. The problem is compounded by high temperatures, nutrient-poor soils, sandstorms (in some places), and long periods of drought.

Developing crop lines that cope with such physical stresses, in addition to biotic stresses such as diseases and insects, is another challenge facing ICRISAT scientists in trying to help farmers stabilize crop production.

ICRISAT's ability to conduct research on drought stress was strengthened this year, with the completion of a spacious rainout shelter at ICRISAT Center.

Experiments in progress with the rainout shelter, which will enable drought treatments to be imposed at controlled times.



Although drought experiments are carried out by ICRISAT scientists under field conditions in widespread areas of the semi-arid tropics, as well as at ICRISAT Center, rainfall at a critical stage in the experiment can invalidate the data obtained and result in a waste of time and resources. The rainout shelter allows drought treatments to be imposed at controlled times, and thus experiments can proceed unhindered throughout the year. It will be particularly useful in studying the effects on crop growth of temporary dry spells during the rainy season and in understanding genotypic differences in response to drought stress.

ICRISAT groundnut physiologists put the shelter to immediate use with an experiment on drought recovery responses. A schedule of experiments with groundnut, sorghum, pearl millet, and early-maturing pigeonpea has been worked out for the next 2 years.

Useful results were obtained in 1986 from continuing field experiments. Forty-two groundnut genotypes identified in earlier drought-resistance screening at ICRISAT Center were tested in a rainfed trial at the drought-prone Anantapur research station in southern India. The cultivar NC Ac 17090 gave 40% more total biomass than the local control TMV 2. Three genotypes with resistance to foliar diseases also did well. One, ICG(FDRS) 55, yielded 1.8 tonnes of dried pods per hectare after receiving only 300 mm of rain.

An international trial to assess 16 groundnut genotypes for drought tolerance was started at sites in India (4), Thailand, the Philippines, Indonesia, Mali, and Niger.

Breeding cold-tolerant sorghums for the highlands of Mexico.

In West Asia and the Mediterranean region, where ICRISAT's cooperative chickpea program with ICARDA (The International Center for Agricultural Research in the Dry Areas) is based, cold is the principal physical stress. The major biotic stress is ascochyta blight, which flourishes in cold, damp weather. Chickpea lines, sown in winter, can give increased yields over those traditionally sown in spring, provided they carry tolerance of both cold and ascochyta blight.

In the screening of 355 newly bred lines this year, 90 were found tolerant of ascochyta blight, 91 of cold, and 10 of both stresses. The 10 lines tolerant of both will be used extensively in the ICRISAT/ICARDA chickpea hybridization program.

Tolerance of cold is also an important factor in breeding improved sorghum lines for the highlands of Mexico. The ICRISAT cereals team based at our sister institute CIMMYT (Centro Internacional de Mejoramiento de Maiz y Trigo) in El Batan, Mexico, evaluated six elite lines this year for adaptation to the low temperatures of the highlands. Their average yield of 5.02 tonnes per hectare was excellent, but further evaluations will be necessary under farmers' dryland conditions.

All of the crop improvement programs at ICRISAT emphasize tolerance of drought and other physical stresses in their research. They are at various stages of progress in developing lines better adapted to these stresses. ■

Exploiting Wild Relatives

In improving crop lines for disease or insect resistance or nutritional factors, an area of considerable promise is the use of wild relatives of commercially cultivated crops. Scientists search the wild species assembled from around the world for desirable traits, and then explore ways in which these traits can be transferred.

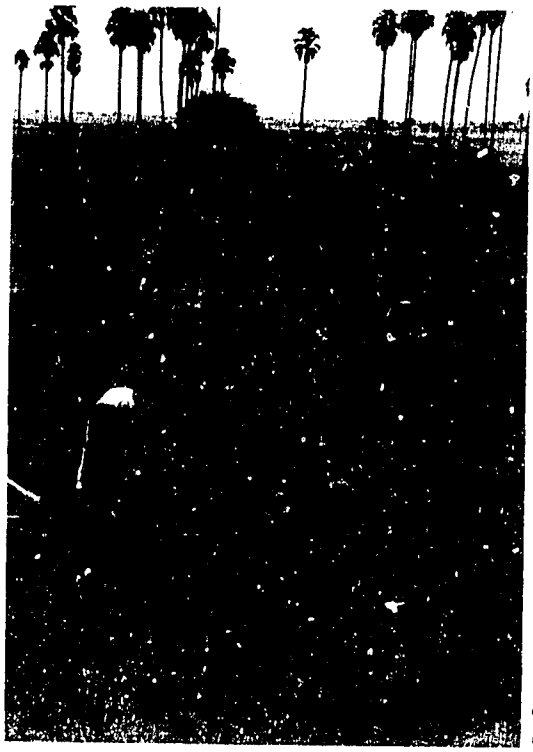
Some of the wild species so identified are readily crossable with cultivated types, others not. Even where the species are compatible and can produce hybrids, cytogenetic manipulation is often necessary to make them fertile.

Based on such work, several disease-resistant lines have been selected and are now being used in national breeding programs. Some resistant lines so produced are being tested as potential new varieties. Work in progress aims both at confirming known resistance and at discovering and using new sources in our accessions. In the process, new genetic combinations with multiple resistances are also identified.

Bud necrosis is the most important virus disease of groundnut in India and is important in some other countries as well. It is caused by the tomato spotted wilt virus. During 1986, resistance to the virus was identified in a wild species of groundnut, *Arachis chacoense*, which, unlike many wild species, can be crossed with cultivated groundnut. High-yielding lines tolerant of tomato spotted wilt virus have been developed.

Resistance to shoot fly was confirmed in 13 of the wild sorghum accessions screened this year. Six of these showed less than 5% damage, compared to 95% in the susceptible sorghum hybrid against which they were tested, and will be used in the breeding program.

For those wild relatives that cannot be readily crossed with cultivated varieties, efforts are made to overcome the problem, using a

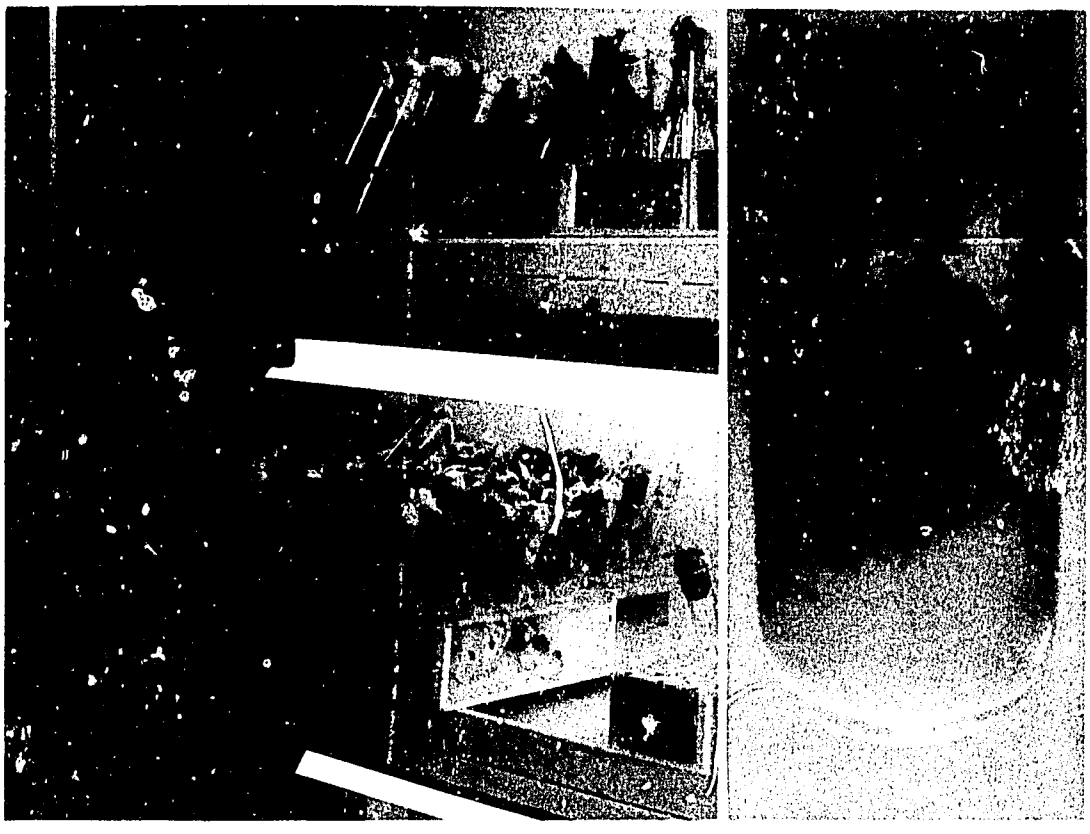


rather complex process. As the crossing does not normally produce well-formed pods in, for example, pigeonpea or groundnut, growth hormones are used to aid formation of pods. The final aim is to widen the range of source material with improved traits for use by breeders.

Two wild relatives of pigeonpea, *Atylosia goensis* and *A. platycarpa*, were found to have better resistance to the fungus that causes phytophthora blight than do the best of ICRISAT's resistant pigeonpea selections. They showed less than 25% blight. They may have some use in future breeding, but at present crosses cannot be successfully made

Groundnut hybrids, derived from crossing cultivated and wild species, are screened in the field for disease resistance.

Studying groundnut pollen under the microscope in the cytogenetics laboratory.



Tissue culture techniques are used to aid shoot formation in groundnut. Close-up shows hybrid shoot growing in the tube.

between these wild species and cultivated pigeonpea.

A. platycarpa is of particular interest to ICRISAT scientists. It carries genes for photoinsensitivity, earliness, and resistance to fusarium wilt and salinity, as well as to phytophthora blight. Although repeated attempts to hybridize it with cultivated pigeonpea have failed, it has been crossed with other wild pigeonpeas, but the seeds so produced are shrivelled. ICRISAT has found a way to remove embryos from those seed and nurture them in the laboratory for growth into plantlets. The plantlets have not yet grown to full plants, but the experiments will continue.

In groundnuts, growth hormones have not to date entirely overcome the incompatibility problem, because pods so formed do not always reach maturity. Efforts at further progress include experiments involving tissue culture techniques.

During 1986, hybrid shoots formed on callus from embryos of a cross between cultivated and wild *Arachis* were grafted onto *A. hypogaea* seedlings. These have survived and shown active growth, so that several hybrid plants are now available for further research. ■

Improving Grain Quality and Nutrition

Good grain qualities and nutritive value are attributes that can help improved crop lines gain ready acceptance by farmers and consumers. Improved varieties and hybrids developed by ICRISAT for adaptation by national programs aim to incorporate these traits as well, in addition to high yields and resistance to drought, diseases, and insects.

To identify cooking or food qualities and nutritional values for incorporation into improved lines, numerous samples need to be routinely tested and evaluated. ICRISAT's biochemists attempt this task, in close cooperation with breeders looking for specific traits.

Pigeonpea scientists were able to report success this year in a step involving improvement of nutrition and grain quality.

Pigeonpea cultivars currently grown produce seeds containing about 21% protein. A high-protein character that increases the protein content to more than 25%—in some cases up to 31%—has been incorporated from wild relatives of pigeonpea into medium-duration lines with good yield.

The high-protein character, transferred to pigeonpea from its wild relatives *Atylosia albicans, A. sericea*, and *A. scarabaeoides*, has shown a high level of stability over the past 4 years. It was tested in 10 different environments, and the protein content of the seed received from those environments was higher than in the control cultivar.

The sulfur-containing amino acids of the high-protein lines were similar to those of the control, indicating that protein quality in

The pigeonpea seed at right was obtained from incorporating a high-protein character from wild relatives. A similar line is now in adaptive yield trials in India.

terms of essential amino acids suffered no loss while the overall protein content increased.

These results clearly show that characters such as high-protein content, large seed size, and high yield can be successfully combined in pigeonpea. One selection from such derivatives has been entered in adaptive yield trials for further evaluation.

Oil and protein contents of 800 groundnut breeding lines grown in various trials in 1985 were estimated this year. The oil content of the lines varied from 37 to 53%, and the protein from 18 to 30%. The lines with oil content of 50% and over were selected for further testing.

Groundnut scientists began a new study to understand the relationship between such quality characters as seed size, oil content, and protein content. No significant relationship was found between oil and protein content in the preliminary results. But within the same genotype, oil content increased as the seed size increased and seed size variation could account for up to 6% variation in oil content.

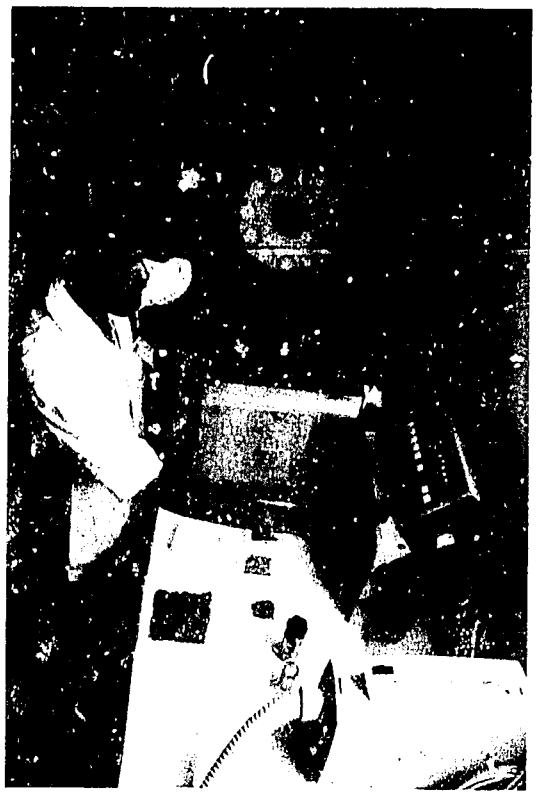
Biological evaluations of leading groundnut cultivars for net protein utilization and protein efficiency ratios were carried out in experiments with male Wistar strain rats. The rats were fed a diet containing 10% protein for evaluating protein efficiency. A standard milk protein, in the form of casein, was used as the control. The net protein utilization obtained with cultivar ICGS 21 was significantly higher than with others. The protein efficiency ratios ranged from 70 to 75% of the standard casein value.

Four new ICRISAT pearl millet varieties, either released or in advanced stages of testing, were evaluated for their quality in making rotis, a popular form of bread in India. The evaluation was done by a taste panel at Haryana Agricultural University in Hisar, India. Ten persons scored the rotis for color and appearance, texture, flavor, taste, and general acceptability. Rotis from released ICRISAT varieties ICMV 1 and ICMH 451 were rated equal to or better than those from the two local control varieties used in the test.

Testing groundnut samples for their oil content, without destroying the seed. More than 800 breeding lines were evaluated this year.

Another grain quality test with pearl millet involved dehulling quality of the grain, an important first step in preparing many African cereal dishes. The dehulling is done in households, village market places, and sometimes in the street by small vendors. The test included cultivars with long, intermediate, and round grains. It showed that round grains not only had a higher seed mass and larger seed size, but also dehulled better when tested by two dehulling machines that operated on different principles. This underscores the desirability of having a much higher proportion of round grains in pearl millet cultivars.

Sorghum was tested for the effect of grain mold on food quality. The dough and roti quality of one mold-resistant sorghum and four mold-susceptible genotypes that showed different levels of mold severity were examined. The molded grain produced poor quality dough with inferior texture, which resulted in unacceptable rotis. Dough from grains of the resistant genotype had good textural properties for making rotis.



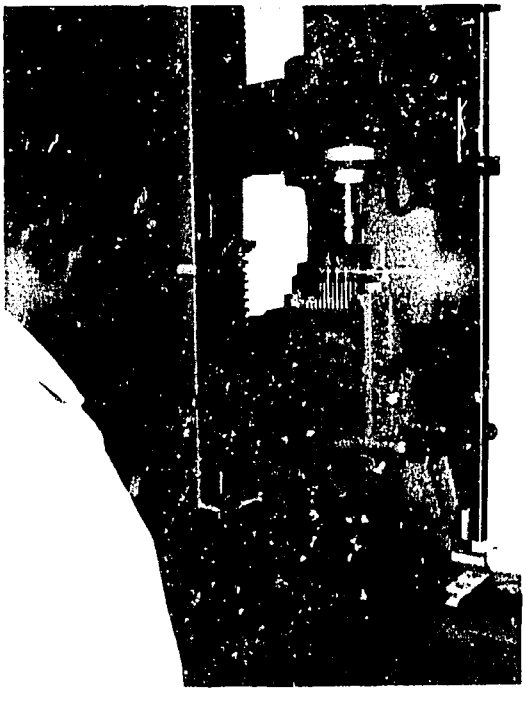
In another experiment, the brewing quality of sorghum was tested for making beer and thin fermented porridges. These are popular uses of the grain in West Africa. In Burkina Faso, traditional sorghum beer, known popularly as dolo, is produced by small-scale breweries from sorghum with red-brown grain. It ferments overnight and is ready the next morning for drinking. Dolo is a relatively clear red liquid with a sweet, pleasant taste and a low alcoholic content (1-4%). Its continued fermentation produces an unpleasant, sour taste.

Three domestic breweries and a local taste panel cooperated with ICRISAT in the experiment. Eight sorghum genotypes, exhibiting differences in grain color, were evaluated for their dolo-making quality. Dolo pro-

Below, pearling sorghum the traditional way in Botswana. At left, milling studies at ICRISAT Center, using more advanced equipment.

Participants at an ICRISAT workshop join in food quality studies at the Biochemistry Lab.

Roti texture of sorghum being studied in laboratory tests.



duced from the brown-grained Dobbs and white-grained Lulu Dwarf cultivars were rated the poorest for beer quality. The local brown-grain variety was the most acceptable, followed by ICRISAT's Framida, M 35-1, and CO-4. The other genotypes also produced acceptable beer.

The color of dolo from the local brown-grain variety was light red and was preferred to the others. Dolo from white-grain sorghum and types such as M 35-1 had a pale yellow color and was new to the panelists. However, other beer-quality features of white-grain types were rated good to acceptable. The inference: not all brown-grain types are suitable for brewing and malting, and some white-grain types can be used to produce dolo, if they are mixed with a proportion of red grains to achieve the desired color. ■

Reaching Farmers' Fields

The payoff for years of work for crop scientists comes when the improved variety or hybrid they have helped develop reaches farmers' fields for general cultivation.

In 1986, nine more ICRISAT finished products attained that goal, and others moved ahead in advanced national trials. Most are both high yielding and resistant to some of the diseases or insects that commonly attack them.

In India, where up to 5 years of testing by the national government normally precedes release of a new crop line, pigeonpea ICPL 87 was officially released to farmers under the name Pragati, which means progress. Pragati is early maturing and can produce two or more crops a season from one planting. It is resistant to wilt, a major disease.

Newspapers reported that farmers had harvested more than 4 tonnes per hectare of this pigeonpea, using the ICRISAT multiple-harvest technique, in on-farm adaptation trials. Average pigeonpea yields in India are 500-800 kg per hectare. This led to a flood of requests for seed from farmers, seed companies, and extension officials from various Indian states. ICRISAT supplied about 500 kg of seed for multiplication.

Pigeonpea ICPL 87, released in India under the name Pragati, growing in a farmer's field in Vikarabad. Requests for seed of this line have been overwhelming.

Farmers who grew the variety in Rangareddy district of Andhra Pradesh were enthusiastic about it because its low height (less than 90 cm) enabled easy spraying with insecticides, and it recorded dry seed yields up to 5.2 tonnes per hectare in two harvests in 180 days. Pragati also found favor with farmers in Maharashtra because of its large seed and superior yield. It is doing well in on-farm trials in Madhya Pradesh, where it can be grown in rotation with wheat.

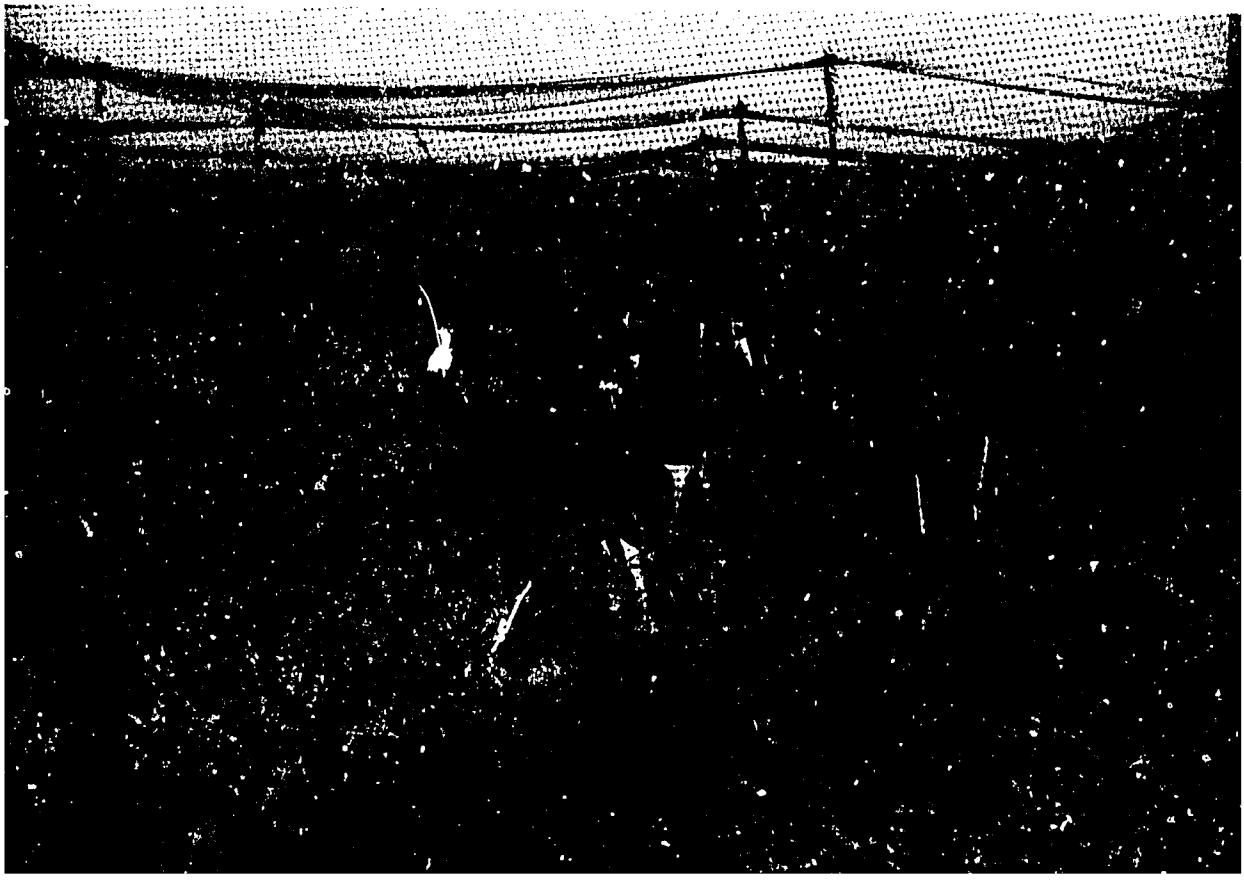
Another ICRISAT early-maturing pigeonpea, ICPL 151, moved to within a step of release by India's Central Variety Release Committee. It is high yielding and has large creamy seeds. The Government of Suriname has requested and received seed of this cultivar for a pilot project there.

ICRISAT's sorghum hybrid ICSH 153 (also called CSH 11 and SPH 221) was released as CSH 11 for cultivation in all regions of India that grow rainy-season sorghum. Thirteen Indian farmers, who grew the hybrid in adaptation trials, had a grain yield of 2.85 tonnes per hectare and a fodder yield of 0.89 tonnes per hectare. Eleven of them found it superior in yield to the popular hybrid, CSH 9. One of the two Indian seed companies multiplying this hybrid sold 171.7 tonnes of its seed in the state of Karnataka this year; a year ago the figure was 18 tonnes.

Two ICRISAT pearl millet hybrids, ICMH 451 and ICMH 501, were released for cultivation across all pearl millet growing regions of India. A crash seed multiplication program by both the private and public sectors is currently under way to produce seed of one of them for the 1987 growing season.

In Syria, two kabuli chickpeas from the ICRISAT/ICARDA collaborative program,

Seed multiplication in progress of ICMH 501, one of two ICRISAT pearl millet hybrids released in India. Several male-sterile parent lines from ICRISAT are being used in national breeding efforts.



Two chickpeas emerging from the ICRISAT/ICARDA collaborative program were released to farmers during 1986. ILC 482 (right foreground) was renamed Ghab 1 before its release in Syria. ILC 3279 (left foreground) was also released in Syria as Ghab 2, as well as in Tunisia

ILC 482 and ILC 3279 were released by the Ministry of Agriculture and Agrarian Reform under the names Ghab 1 and Ghab 2, respectively, for winter sowing. They are tolerant of cold and resistant to ascochyta blight, two traits necessary for winter cultivation. On average, in 114 winter-sown tests between 1980 and 1986, Ghab 1 yielded 100% more grain (1.57 t/ha) than the Syrian landrace chickpea sown in the spring. In 75 tests between 1982 and 1986, Ghab 2 yielded 60% more on average than the spring-sown landrace.

The Syrian on-farm trials have been adopted by several national programs, including those of Morocco, Tunisia, Turkey, Algeria, Oman, Lebanon, and Egypt, and the programs are using the on-farm trial results to release ICRISAT/ICARDA cultivars. Tunisia, for example, released cultivars ILC 3279 and FLIP 83-46C for commercial cultivation during 1986.

In Ethiopia, two short-duration desi chickpea varieties, selected from crosses supplied by ICRISAT, were officially released to farmers. In Nepal, ICCV 1, a high-yielding ICRISAT desi chickpea cultivar, performed well in the lower plains and was proposed for release to farmers. ICCL 81248, proposed for release as S1 in Bangladesh, again gave impressive results in on-farm tests with yields of around 3 tonnes per hectare. In Burma, a wilt-resistant desi line from ICRISAT moved into the prerelease multiplication stage following several years of tests.

Requests for seed of two ICRISAT kabuli chickpeas, ICCV 2 and ICCV 5, have been received from the Andhra Pradesh Seeds Corporation in India. Following their strong performance in tests, the Andhra Pradesh government plans to multiply and distribute their seeds to farmers.

ICRISAT's first groundnut to reach farmers' fields, ICGS 11, was released last year for postrainy-season irrigated cultivation in central and peninsular India. The Indian government has now advanced it to prerelease trials in five states of northern India as well.

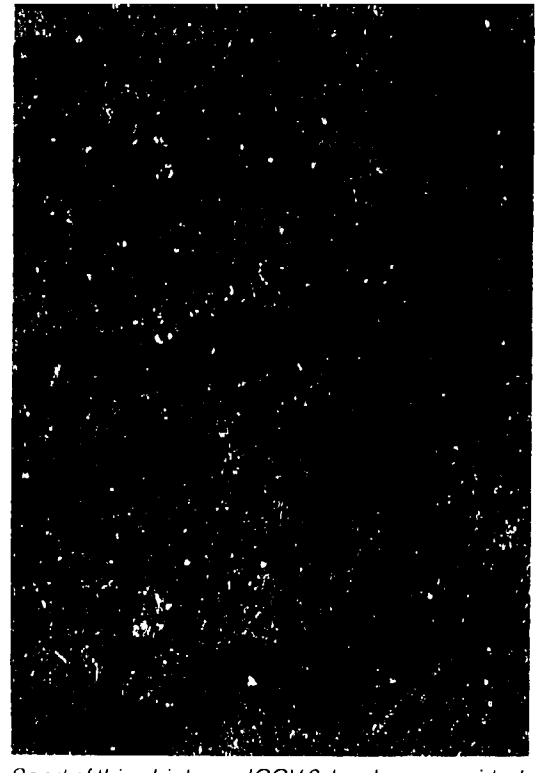
ICRISAT's first crop variety to be released in India, pearl millet ICMV 1 (also called

WC-C75), continues to find favor among farmers 4 years after its release because of its high grain and fodder yield. In 1986, seed production of ICMV 1 had spread to nine states of India, representing 60 to 65% of the country's millet-growing area.

The demand for breeder seed of this variety continues. ICRISAT was able to supply 560 kg to seed production agencies in India from January 1985 to April 1986 of the 900 kg they had requested. The Indian Council of Agricultural Research estimates there will be enough seed of ICMV 1 to plant 1.5 million hectares during the 1987 rainy season. Zambia and the Yemen Arab Republic are also planning to release this variety.

Reports were received from Sudan of the continued popularity there of the ICRISAT sorghum hybrid Hageen Durra 1, which did well in the Sudan drought 2 years ago. The Global 2000 Foundation, working in Sudan, has been using Hageen Durra 1 extensively in their demonstration plots. They report the hybrid has done extremely well in locations where the annual rainfall is over 400 mm and that farmers and officials continue to be impressed with its performance.

ICRISAT sorghum varieties are also nearing release in other parts of Africa: ICSV 1002 BF continues to demonstrate yield stability in farmers' fields in Burkina Faso and will be ready for naming and formal release in 1987, and S 35 and S 34 have been found high-yielding in trials in Cameroon. S 35 is a 90-day variety for the dry regions there, and S 34 a 110-day variety for the wet regions. ■



Seed of this chickpea, ICCV 2, has been provided to the Andhra Pradesh Seeds Corporation in India, pending its release

Nine finished varieties or hybrids emerging from ICRISAT's research reached farmers' fields this year. Details:

Chickpea	*ILC 482 (Ghab 1)*	*Syria*
	ILC 3279 (Ghab 2)	*Syria and Tunisia*
	FLIP 83-46C	*Tunisia*
	K 850 × F 378 and JG 62 × Radhey	*Ethiopia*
Pearl Millet	*ICMH 451 and ICMH 501*	*India*
Pigeonpea	*ICPL 87 (Pragati)*	*India*
Sorghum	*ICSH 153 (CSH 11)*	*India*

Training Activities

The training of agriculturists from countries of the semi-arid tropics is one sure way of strengthening research capabilities in those countries, so that they can play an active role in evolving and using improved technologies.

Since 1974, nearly 1300 persons from 74 countries have completed training at ICRISAT Center, and the vast majority have come from SAT countries. Many are now working as research assistants, scientists, or extension officers in their home countries, and some are managing research stations.

This year there were 181 participants from 44 countries in individualized and intensive training programs at ICRISAT Center. Forty others received training—long-term or short-term—from ICRISAT scientists posted in West Africa, southern Africa, and Mexico.

Among the 181 trainees at ICRISAT Center in 1986 were 30 in-service fellows, holding senior or midlevel scientific positions in the national research programs of 15 countries. They took part in intensive skill-development programs in pathology, entomology, microbiology, cytogenetics and physiology, plant breeding, cropping systems, soil fertility, and farm development.

A total of 100 in-service participants from 35 countries were trained for up to 6 months at ICRISAT Center in crop improvement, crop production, and resource management. This is ICRISAT's major training program and has been operational for 12 years.

Postdoctoral participants (15) came from five countries to ICRISAT Center—eight as international interns, five as research fel-

International intern from the UK studies aspects of millet physiology.

Studying phytophthora blight in pigeonpea is this postdoctoral fellow from India.

Research scholar from India studying urea changes and losses in soils.

lows, and two as postdoctoral fellows. Their crop-related studies were in sorghum and millet physiology; sorghum entomology; sorghum pathology; pigeonpea breeding; groundnut virology; groundnut entomology; and chickpea, pigeonpea, and groundnut pathology. Their studies in resource management were focused on the effect of topography on sorghum production, fertilizer practices on farmers' fields, effects of land fragmentation, and groundnut marketing.

Thirty-one students from 16 universities and 12 countries conducted theses research at ICRISAT Center on a wide range of topics. Their research included all five mandate crops and the disciplines of physiology, pathology, and breeding. Studies in resource management included biophysical aspects, such as cropping systems, intercropping, agroforestry, and crop responses to soil fertilization, residual nitrogen, and groundwater availability, as well as socioeconomic factors, such as rainfall insurance, adoption behavior, household economics, and women's participation in agricultural development.

Thus, postdoctoral fellows and research scholars not merely take back with them valuable research experience from ICRISAT, but also add to the knowledge base available at ICRISAT Center for further dissemination and use

And in the apprentice program, five participants from three countries were associated with ICRISAT scientists in work-study projects relating to groundnut pathology and entomology, millet breeding, and chickpea pathology.

Away from ICRISAT's headquarters, plans moved forward for the establishment of an organized training program at the ICRISAT

Former in-service trainees visit ICRISAT Center and get briefed by ICRISAT's cereals coordinator for eastern Africa (extreme right).

Sahelian Center (ISC) near Niamey, Niger. A 1.5 hectare block of land was acquired from the city of Niamey for the ISC Training and Visitors' Center that will accommodate 15 French-speaking in-service trainees each session.

A training officer will be appointed to conduct training activities at the ISC for West African countries. Most important will be in-service training for research support staff through a cropping cycle in millet and groundnut improvement and resource management. Short-term training courses on specific subjects will also be organized in cooperation with national agricultural research institutions in West Africa at locations other than the Sahelian Center. The ISC training officer will also develop curricula for sorghum training at the location where ICRISAT's regional sorghum team for West Africa will be based.

In training at the ISC this year, six university students from Niger were supervised by ICRISAT staff, and four West German students worked there on their master's degrees in a collaborative project with Hohenheim University. A technician from Project Formation, Protection des Vegetaux, evaluated varietal resistance to *Striga* in pots; a student from Kolo studied seedling establishment under drought; and two students from the University of Niger did project work on root development and growth analysis.

In the SADCC/ICRISAT cereals improvement project at Matapos, near Bulawayo, Zimbabwe, nine scientists from five southern African countries participated in a 4-week intensive course on sorghum and millet improvement. Staff from ICRISAT Center helped plan and conduct this course.

Eight scientists were trained during 1986 in sorghum breeding and agronomy by the ICRISAT team based at CIMMYT in El Batan, Mexico. The participants came from El Salvador, Guatemala, Mexico, and Nicaragua.

ICRISAT's training activities during the year thus covered a wide range, whether in terms of crops and disciplines, levels of specialization, or geographic spread. ■

Widening Research Networks in Africa and Asia

ICRISAT's research mandate concerns many parts of the world. But its work can have an impact only with the active cooperation of the many national and regional organizations at work in specific countries or regions.

The Institute has been increasingly adopting a regional network approach to help foster such cooperation. The approach seeks to strengthen national research capability and aid transfer of technology, so that farmers can more readily benefit from research. And by tapping the resources of scientists already working in a region, the approach adds to the pool of knowledge available, based on which solutions can be devised.

Activities during the year to initiate and strengthen such networks in some of ICRISAT's priority regions—West Africa, southern Africa, eastern Africa, and Asia—are outlined here.

West Africa

The beginning of groundnut research at the ICRISAT Sahelian Center (ISC) in Niger this year adds a new dimension to ICRISAT's work in West Africa. Research is already well under way at the ISC on pearl millet, cowpea (with our sister institute IITA, the International Institute of Tropical Agriculture), and improved resource management systems for those crops; in Burkina Faso on sorghum and pearl millet; and in Mali on sorghum, pearl millet, and pigeonpea.

Members of an advisory committee for sorghum research in West Africa observe off-season nursery in Burkina Faso.

The ISC groundnut improvement program will seek to develop high-yielding breeding lines adapted to various agroecological zones of West Africa, by incorporating into those lines resistances to biotic and physical stress factors now limiting production, and to develop agronomic practices suitable for small farmers of the region.

An agronomist has already been appointed to the Sahelian Center groundnut team at the ISC, and a breeder and a pathologist will join him in early 1987. Meanwhile, a pathologist from ICRISAT Center was assigned there during 1986 to survey the groundnut diseases in Niger, identify suitable locations for 1987 rainy-season trials, and help prepare the work plan for the groundnut program.

To start the West Africa regional groundnut program, 162 high-yielding breeding lines and 67 germplasm lines with disease and drought resistance, selected from ICRISAT Center, were multiplied in field plots at Bengou, Niger, during the 1986 rainy season. These lines will form a genetic base for future research at the ISC.

The ICRISAT staff will work in close cooperation with national programs and other international groundnut researchers in West Africa, including scientists from the French oilseed research organization, IRHO, and the USA's Peanut Collaborative Research Support Program (Peanut CRSP) working in Burkina Faso, Guinea, Niger, and Nigeria. Useful contacts have already been made with these scientists and those from national programs in West Africa.

Groundnut was once an export crop for several African countries but, with produc-

Early-maturing groundnuts from ICRISAT Center did well when evaluated during the rainy season at a national experiment station in southern Niger.

ion declining, they have now become importers of this crop. ICRISAT's efforts will aim to help reverse this trend.

A regional pearl millet workshop, held jointly with the Nigerien national program, was attended by 29 scientists from eight countries. It identified areas where national programs and the ISC could usefully cooperate, based on a field tour and review of ongoing research.

The Sahelian Center, where construction is now in progress and will be completed in 1988, is the headquarters for all of ICRISAT's work in West Africa. It constitutes ICRISAT's major presence on the continent—but not the only one.

To meet the needs of sorghum improvement and related resource management research in West Africa, a regional research team will be established in the Sudanian ecological zone at a location being identified by a team of experts, in consultation with national governments. The Sudanian zone includes parts of Benin, Burkina Faso, Cameroon, Chad, Gambia, Guinea, Mali, Niger, Nigeria, and Senegal.

The regional sorghum research team will include a network coordinator, two breeders, a pathologist, two agronomists, an entomologist, and an economist. It will expand on sorghum research that has been done on a more limited scale for the past 12 years by a smaller ICRISAT team in Burkina Faso. ICRISAT also has a two-man sorghum and millet improvement team stationed in Mali. They also introduced pigeonpea as a crop, to help fix nitrogen in the soil, and pigeonpea is being grown as an intercrop with maize. The Mali program celebrated its 10th anniversary this year.

Southern Africa

In southern Africa, ICRISAT has a regional team for sorghum and millet improvement, based at the Matopos Research Station near Bulawayo, Zimbabwe, serving the nine countries of the Southern African Development Coordination Conference (SADCC). Already in position are a program coordinator, who is also Executive Director of ICRISAT's southern African programs, two plant breeders, an agronomist, a pathologist, and an entomologist. An economist, a food technologist, and later a training officer will be added to this team.

To meet its objective of strengthening national research capability within the region on sorghum, pearl millet, and finger millet, the program has conducted research and training activities, monitoring tours and workshops, and offered support services in station development.

Based on annual planning meetings, tours, and frequent discussions, several yield-limiting factors have been identified within the region, and suitable locations have been selected for cooperative research on specific problems. Progress was made in 1986 on systematic screening of breeding stocks for resistance to major diseases in sorghum and pearl millet, and methods are now being developed to screen for adaptation of other desirable traits.

As trained manpower is a key component in national research capability, education and training of scientists within the region have also been given priority. The educational component is handled by the Collaborative Research Support Program on Sorghum and Pearl Millet (INTSORMIL), a consortium of universities in the USA, and support for this program comes from the U.S. Agency for International Development (USAID). Some 70 persons from within the region will be trained in various disciplines over 10 years, so that national programs can have requisite capabilities for conducting research.

Short-term training is also offered. A course for technicians was held in 1986, and a second one is planned for March 1987. Technicians from within the region are also helped to enroll as in-service trainees or fellows at ICRISAT Center.

Assessing a sorghum field in Zimbabwe are participating scientists in the regional network established there for southern Africa.

Scientists in the regional program have planted an off-season nursery at Mzarabani, Zimbabwe, to multiply seeds, make crosses, and advance breeding lines rapidly. This facility has already been utilized by the national programs of Botswana, Malawi, and Zimbabwe. In addition, the program has begun to help improve field layout, farm equipment, and seed storage facilities at national research stations, so that more reliable research results can be obtained.

Similar research and network support activities for groundnut in southern Africa are undertaken by an ICRISAT pathologist and a breeder based at Chitedze Research Station near Lilongwe, Malawi. The team has assembled nurseries of locally adapted genotypes for assessment within the region. At the request of national programs in the region, this team is being expanded to include more scientists who will cover other constraints to groundnut production in southern Africa.

Eastern Africa

ICRISAT also plans to establish a regional team for sorghum and millet improvement in eastern Africa, where it is now represented only by a SAFGRAD/ICRISAT plant breeder/coordinator based in Kenya. He will be joined by an agronomist and an entomologist, and other scientists will be posted within national programs. This cereals improvement team will serve all of eastern Africa and the two Yemens.

Groundnut, pigeonpea, and chickpea are also important crops to countries in eastern

Africa, and ICRISAT has plans to establish a research network there to work with national programs on improvement of those legumes. A consultative group meeting with scientists in the region, held in Ethiopia in December 1986, strongly urged that such an effort be put in place.

ICRISAT's long-range plans, approved by the Governing Board, also call for the Institute to begin research work in eastern Africa on transfer of Vertisol management technology to farmers in cooperation with national agricultural research systems, our sister institute ILCA (The International Livestock Centre for Africa), and IBSRAM (The International Board of Soil Research and Management). Agroclimatic analysis has been completed for the start of this work in representative areas of Ethiopia and Sudan. ICRISAT has had considerable success in India in developing and transferring technology to increase production on the deep black soils.

Asia

In South and Southeast Asia, ICRISAT initiated this year an Asian Grain Legumes Network to strengthen the collaboration between its Legumes Program at ICRISAT

Participants at a consultative meeting on grain legumes visit chickpea experiments in Ethiopia. The group urged that ICRISAT establish a research network for legumes in eastern Africa.

ICRISAT's Asian Grain Legumes Network got active soon after its inception this year. Above, cooperators from Burma discuss chickpea experiment with an ICRISAT breeder (center). Below, a cooperating scientist observes pigeonpea growing in the People's Republic of China.

Center and scientists throughout Asia working on groundnut, chickpea, and pigeonpea. This network resulted from two meetings attended by Asian scientists and government officials at ICRISAT in 1983 and 1985. The network Coordinator is based at ICRISAT Center.

Countries in the network include Bangladesh, Burma, the People's Republic of China, India, Indonesia, Nepal, Pakistan, the Philippines, Sri Lanka, and Thailand. The Coordinator visited all of these countries this year to help integrate network activities with those of regional and international organizations working in the area, to conduct with national governments preliminary surveys that helped identify research needs, and to plan a program of activities. Inquiries were made in each country on the need to collect germplasm of the three legume crops and to assess the need for special projects and training.

Scientists in the network countries can select improved germplasm from ICRISAT Center to fit a wide range of local cropping patterns. They may also obtain germplasm with resistances to diseases and insects and agronomic information on crop responses to various cropping systems.

The network will provide general and specialized training at ICRISAT Center for technicians and scientists working on these crops. ICRISAT scientists will also be available to visit participating countries and help strengthen research programs on these crops.

The network builds on memoranda of understanding with governments of participating countries. Such agreements were signed with Bangladesh and Burma during 1986, adding to those existing with Pakistan, the Philippines, and Thailand. More will be signed in 1987. ■

In Other Research

- Present vegetable-type pigeonpea varieties all take longer to grow than the increasingly popular short-duration lines that mature in 90 to 150 days. ICRISAT scientists have now developed high-yielding, short-duration pigeonpea with large seeds that may be used for both vegetable and dry grain crops.
- In Burkina Faso, four ICRISAT pearl millet varieties were accepted for large-scale testing by the government on farmers' fields after strong showings in multilocational trials over several years. Variety IKMV 8201 is early maturing (90 days) and was recommended for late-planting situations. Its long-term average yield is 870 kg per hectare, compared with 390 kg/ha for the control variety in the tests. IKMP 2 and IKMP 5, which yielded 560 to 570 kg/ha, compared with 150 kg/ha for the control, are of intermediate maturity (110-120 days) and are recommended for normal planting in the 500-600 mm annual rainfall zone. IKMP 3 is late maturing and was recommended for normal planting situations in the 700-900 mm annual rainfall zone. Its average yield is 1570 kg/ha, compared with 1100 kg/ha for the control.
- A pearl millet hybrid, ICMH 851009, on a new downy mildew and rust resistant male-sterile line, 852A, was the highest-yielding entry over 13 locations in India in the 1986 International Pearl Millet Adaptation Trial (IPMAT). This hybrid outyielded the best commercial hybrid by 21%.

- Progress continued to be made in research against the parasitic weed *Striga*, which destroys sorghum plants at widespread locations in Asia and Africa. In screening at ICRISAT Center, five more advanced lines proved resistant to *Striga asiatica*, which grows in both Asia and Africa. And at Kamboinse, Burkina Faso, 10 of the 200 breeding lines screened were resistant to *Striga hermonthica*, the species most common in Africa.

  In field tests, two *Striga*-resistant sorghum varieties did well in Sudan and are being considered for large-scale, on-farm tests in 1987. Broad-spectrum resistance to *Striga* was also confirmed in a variety in Niger.
- In Niger, peanut clump virus disease has been found more widely distributed and severe than previously expected. It is transmitted through seed of both groundnut and foxtail millet, *Setaria italica*.
- A nonnodulating chickpea mutant has been isolated from field-grown plants, and it can be used as a nonfixing control to measure symbiotic nitrogen fixation in chickpea.
- Two long-duration pigeonpea lines with resistance to sterility mosaic, ICPL 366 and ICPL 8398, are in all-India coordinated trials, following their performance in preliminary tests.
- Pearl millet lines bred at ICRISAT Center continued to perform well in southern Africa. An intervarietal composite did well in Zambia and Zimbabwe, and a selection from this composite reached advanced adaptive trials in India.
- In Zambia, two dwarf varieties of pearl millet, NC(d2) and IVC(d2), and two other ICRISAT varieties, ICMV 82132 and ICMV 83104, have been selected for national demonstrations.
- An International Symposium on Agrometeorology and Plant Protection in the Semi-Arid Zones was held 8-12 December in Niamey, Niger. Attended by 66 scientists from 22 countries, the symposium evolved recommendations for applying agroclimatic information to protect crops against insects and diseases.

  The symposium was organized in cooperation with the World Meteorological Organization, and had several cosponsors: the Food and Agriculture Organization, the United Nations Development Programme, the United Nations Environment Programme, the Organization for African Unity, and the Technical Centre for Agricultural and Rural Cooperation of the Netherlands.

■

ICRISAT Senior Staff—as of December 1986

ICRISAT Center

Administration

L.D. Swindale, Director General
J.S. Kanwar, Deputy Director General
M. Goon, Assistant Director General (Administration)
S.P. Ambrose, Principal Government Liaison Officer (until May)
K.B. Srinivasan, Assistant Director General (Liaison) (from Jun)
B.C.G. Gunasekera, Advisor to Director General for Donor Relations
S.J. Phillips, Special Assistant to Director General for Educational Affairs
W.E. Urban, Advisor in Research Management Systems (from Aug)
V. Balasubramanian, Sr Executive Officer (Director General's Office)
Joyce Gay, Sr Adm Secretary to the DG
M.S.S. Reddy, Scientist (on contract)
Sunetra Sagar, Sr Adm Secretary to the DDG
S. Krishnan, Asst Manager (Admn), Office of Adviser to the DG for Donor Relations
S. Ramachandran, Adm Officer, Office of Adviser to the DG for Donor Relations (until Aug)
C. Geetha, Sr Secretary, Office of the ADG (Admn)
P. Sosamma Nair, Sr Secretary, Office of the ADG (Liaison)
D. Mitra, Fiscal Manager
A. Banerji, Asst Manager (Fiscal)
V.S. Swaminathan, Sr Accounts Officer
A.N. Venkataswamy, Accounts Officer
C.P. Rajagopalan, Accounts Officer
P.A.V.N. Kumud Nath, Accounts Officer
B.K. Vasu, Accounts Officer
K. Narayana Murthy, Accounts Officer
B.K. Johri, Personnel Manager
P.M. Menon, Asst Personnel Manager (from Feb)
N.S.L. Kumar, Sr Personnel Officer
P. Suryanarayana, Sr Personnel Officer
A.J. Rama Rao, Sr Secretary (Personnel)
R. Vaidyanathan, Purchase and Stores Manager (on sabbatic until Apr)
C.R. Krishnan, Asst Manager (Purchase and Stores)
K.P. Nair, Sr Purchase Officer
D.K. Mehta, Sr Stores Officer
D.V. Rama Raju, Sr Purchase Officer
K.C. Saxena, Sr Stores Officer
K.R. Natarajan, Shipping and Purchase Officer
Joseph Banji, Purchase Officer
A. Lakshminarayana, Sr Scientific Liaison Officer (Visitors' Services)
Harish Sethi, Scientific Liaison Officer
Georgina Fredericks, Adm Officer (Visitors' Services)
K.K. Sood, Sr Security Officer
A. Ekbote, Security Officer
K.K. Vij, Sr Adm Officer (Delhi Office)
V. Lakshmanan, Asst Manager (Admn)
N. Surya Prakash Rao, Sr Resident Medical Officer
R. Narsing Reddy, Transport Officer (until Sep)
G. Vijayakumar, Transport Officer
K. Jagannadham, Adm Officer (Transport)
A. Rama Murthy, Travel Officer

Research Programs

Cereals

Program Office

J.M.J. de Wet, Program Director, Cereals (from Jun)
K. Santhanam, Asst Manager (Admn) (from Aug)
S.P. Jaya Kumar, Adm Officer (until Aug)
Nirmala Kumar, Adm Officer

Sorghum Group

S.Z. Mukuru, Principal Plant Breeder (Program Leader until May) (on sabbatic)
L.K. Mughogho, Principal Plant Pathologist
J.M. Peacock, Principal Plant Physiologist
K. Leuschner, Principal Cereals Entomologist (until Nov)
D.S. Murty, Plant Breeder (on leave from Jul)
B.L. Agrawal, Plant Breeder
Belum V.S. Reddy, Plant Breeder
P.K. Vaidya, Plant Breeder
N. Seetharama, Plant Physiologist
P. Soman, Plant Physiologist
Suresh Pande, Plant Pathologist
R. Bandyopadhyay, Plant Pathologist
S.L. Taneja, Entomologist
H.C. Sharma, Entomologist (on sabbatic from Nov)
H.D. Patil, Sr Research Associate
K. David Nicodemus, Sr Research Associate
P. Ramesh, Research Fellow
N.F. Beninati, International Intern (until Nov)
D.J. Flower, International Intern (from Feb)

Pearl Millet Group

S.B. King, Principal Plant Pathologist (Program Leader until May)
F.R. Bidinger, Principal Plant Physiologist
J.R. Witcombe, Principal Plant Breeder
K.K. Lee, Principal Cereals Microbiologist

K.N. Rai, Plant Breeder
B.S. Talukdar, Plant Breeder
Pheru Singh, Plant Breeder
S.B. Chavan, Plant Breeder
G. Alagarswamy, Plant Physiologist (on secondment)
V. Mahalakshmi, Plant Physiologist
S.D. Singh, Plant Pathologist
R.P. Thakur, Plant Pathologist (on sabbatic from Jul)
S.P. Wani, Microbiologist
K.R. Krishna, Microbiologist
P.Q. Craufurd, International Intern
C.T. Hash Jr., International Intern (from Mar)

Kenya

Brhane Gebrekidan, SAFGRAD/ICRISAT Coordinator for Sorghum and Millet, Eastern and Southern Africa (until Apr)
V.Y. Guiragossian, SAFGRAD/ICRISAT Coordinator for Sorghum and Millet, Eastern Africa (from Jun)

Sudan

R.P. Jain, Principal Millet Breeder (until Sep)

Mexico

V.Y. Guiragossian, Principal Sorghum Breeder (until May)
C.L. Paul, Principal Sorghum Agronomist
R. Clara, Scientist, Sorghum Breeder

Legumes

Program Office

Y.L. Nene, Principal Plant Pathologist and Acting Program Director, Legumes
D.G. Faris, Principal Coordinator, Asian Grain Legumes Network
D.M. Pawar, Sr Agricultural Officer (Cooperative Trials)
P. Subrahmanyam, Sr Adm Officer (until Aug)
Surendra Mohan, Sr Adm Officer (from Aug)
P. Rama Murthy, Adm Officer, Legumes
G.J. Michael, Adm Officer (AGLN) (from Aug)

Pulses Group

W. Reed, Principal Entomologist
C. Johansen, Principal Agronomist
H.A. van Rheenen, Principal Plant Breeder, Chickpea
Laxman Singh, Principal Plant Breeder, Pigeonpea
A.B.S. King, Principal Entomologist, ICRISAT/TDRI (from Apr)
J. Arihara, Associate Physiologist
N. Ae, Associate Microbiologist
H.J. Hansen, Asst Plant Pathologist, ICRISAT/DANIDA (from Jun)
K. Okada, Asst Microbiologist (from Dec)
D. Sharma, Sr Plant Breeder, Pigeonpea (from May)
K.C. Jain, Plant Breeder, Pigeonpea
Onkar Singh, Plant Breeder, Chickpea
K.B. Saxena, Plant Breeder, Pigeonpea
S.S. Lateef, Entomologist
M.P. Haware, Plant Pathologist (on leave from Nov)
S.C. Sethi, Plant Breeder, Chickpea
N.P. Saxena, Agronomist
C.L.L. Gowda, Plant Breeder, Chickpea
O.P. Rupela, Agronomist (Microbiology)
J.V.D.K. Kumar Rao, Agronomist (Microbiology)
A.M. Ghanekar, Plant Pathologist
Jagdish Kumar, Plant Breeder, Chickpea
S. Sithanantham, Entomologist
S.C. Gupta, Plant Breeder, Pigeonpea
M.V. Reddy, Plant Pathologist
Y.C. Chauhan, Agronomist (Physiology)
S.B. Sharma, Plant Nematologist (from Nov)
M.D. Gupta, Sr Research Associate (on study leave until Sep)
N.V. Ratnam, Sr Research Associate
J.H. Miranda, Sr Research Associate, Chickpea
L. Krishna Murthy, Sr Research Associate
I.S. Dundas, International Intern (until Oct)
P.K. Anand Rao, Postdoctoral Fellow
Nandita Sarkar, Postdoctoral Fellow (from Jun)

Groundnut Group

R.W. Gibbons, Principal Plant Breeder (Program Leader until May)
D. McDonald, Principal Plant Pathologist
J.P. Moss, Principal Cytogeneticist
D.V.R. Reddy, Principal Plant Virologist
J.H. Williams, Principal Plant Physiologist
J.A. Wightman, Principal Entomologist
S.N. Nigam, Principal Plant Breeder (from Jun)
F. Waliyar, Asst Plant Pathologist (from Sep)
L.J. Reddy, Plant Breeder (on sabbatic until Jun)
P. Subrahmanyam, Plant Pathologist
P.T.C. Nambiar, Microbiologist
P.W. Amin, Entomologist
G.V. Ranga Rao, Entomologist
A.K. Singh, Cytogeneticist (on sabbatic from Jul)
V.K. Mehan, Plant Pathologist
D.C. Sastri, Cytogeneticist
M.J. Vasudeva Rao, Plant Breeder
S.L. Dwivedi, Plant Breeder
R.C. Nageswara Rao, Plant Physiologist

V.M. Ramraj, Plant Physiologist
H.A. Hobbs, International Intern (until Feb)
K.M. Dick, International Intern (until Dec)
S. Nahdi, Research Fellow (until Mar)

Syria

K.B. Singh, Principal Chickpea Breeder
M.P. Haware, Principal Chickpea Pathologist (from Nov)

Pakistan

M.S. Rahman, Principal Chickpea Breeder/Plant Pathologist

Resource Management

Program Office

M. von Oppen, Program Director
D. Sharma, Coordinator, On-farm Research (until May)
S.K. Sharma, Sr Research Associate
R.S. Aiyer, Sr Adm Officer
Surendra Mohan, Sr Adm Officer (until Aug)
S. Ramachandran, Adm Officer (from Aug)

Agronomy Group

S.M. Virmani, Principal Agroclimatologist
J.R. Burford, Principal Soil Chemist (on sabbatic from Jun)
C.W. Hong, Principal Soil Scientist (ICRISAT/IFDC) (until May)
C.K. Ong, Principal Agronomist, Cropping Systems
A.B.S. King, Cropping Systems Entomologist (ICRISAT/TDRI) (until Apr)
R.J. Van Den Beldt, Principal Agronomist, Agroforestry
A. Schütt, Asst Engineer, Soil Fertility Unit (ICRISAT/University of Hamburg)
Piara Singh, Soil Scientist
A.K.S. Huda, Agroclimatologist
K.L. Sahrawat, Soil Chemist
T.J. Rego, Soil Scientist
M.R. Rao, Agronomist (until Jul)
M.S. Reddy, Agronomist (on leave)
M. Natarajan, Agronomist (on sabbatic from Mar)
A. Ramakrishna, Agronomist (from Oct)
C.S. Pawar, Entomologist
A.A.H. Khan, Engineer
R. Tabo, Postdoctoral Fellow (from Jul)

Engineering Group

K.B. Laryea, Principal Soil Physicist
T. Takenaga, Principal Agricultural Engineer
Sardar Singh, Soil Scientist
K.L. Srivastava, Agricultural Engineer
R.K. Bansal, Agricultural Engineer (on sabbatic from Oct)
R.C. Sachan, Agricultural Engineer
Prabhakar Pathak, Agricultural Engineer
N.K. Awadhwal, Agricultural Engineer/Soil Physicist
V.M. Mayande, Engineer (on study leave until Aug)

Economics Group

T.S. Walker, Principal Economist
P.J. Matlon, Principal Economist (from Sep)
R.A.E. Müller, Principal Economist
Karen Ann Dvořák, International Intern (until Nov) and Principal Economist (ICRISAT/IFDC) (from Nov)
N.S. Jodha, Sr Economist
R.N. Athavale, Sr Hydrologist (on contract)
R.D. Ghodake, Economist (on leave until Dec)
R.P. Singh, Economist
K.G. Kshirsagar, Sr Research Associate
K.V. Subba Rao, Sr Research Associate
M.J. Bhende, Sr Research Associate
V. Bhaskar Rao, Sr Research Associate
P. Parthasarathy Rao, Sr Research Associate
N.V. Narasimham, Research Fellow (until Aug)
V. Ballabh, Research Fellow (until Jan)

Support Programs

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Umaid Singh, Biochemist
V. Subramanian, Biochemist
S. Sivaramakrishnan, Plant Biochemist/Physiologist
T.A. Krishnamurthi, Sr Adm Officer (until Aug)
P. Subrahmanyam, Sr Adm Officer (from Aug)
Santosh Gurtu, Sr Research Associate
M.S. Kherdekar, Sr Research Associate
S. Suryaprakash, Sr Research Associate

Electron Microscopy

A.K. Murthy, Engineer

Genetic Resources

M.H. Mengesha, Principal Germplasm Botanist and Program Leader

W.H. Skrdla, Germplasm Botanist (until Feb)
K.E. Prasada Rao, Sr Botanist
R.P.S. Pundir, Botanist
V. Ramanatha Rao, Botanist
S. Appa Rao, Botanist
P. Remanandan, Botanist
T.R.K. Satyanarayana, Adm Officer

Plant Quarantine

B.K. Varma, Chief Plant Quarantine Officer
Upendra Ravi, Sr Research Associate
N. Rajamani, Sr Adm Officer

Fellowships and Training

D.L. Oswan, Principal Training Officer
A.S. Murthy, Sr Training Officer (until Mar)
B. Diwakar, Sr Training Officer
T. Nagur, Sr Training Officer (on sabbatic until May)
S.K. Dasgupta, Sr Training Officer
(on sabbatic from Nov)
Faujdar Singh, Training Officer
V.S. Raju, Sr Secretary

Information Services

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Susan D. Feakin, Research Editor
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Madhu Reddy, Editor
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Murari Singh, Statistician

Computer Services

J.W. Estes, Computer Services Officer
S.M. Luthra, Manager (Computer Services)
J. Sai Prasad, Asst Manager (Computer Services)
T.B.R.N. Gupta, Sr Computer Programmer/Analyst
C. Kameswara Rao, Computer Programmer/Analyst
S.V. Nanda Kishore, Computer Programmer/Analyst
J. Gnanasekharan, Computer Programmer/Analyst

Library and Documentation Services

L.J. Haravu, Manager
P.K. Sinha, Sr Documentation Officer
P.S. Jadhav, Sr Library Officer
S. Prasannalakshmi, Library Officer

Housing and Food Services

G.W. Conover, Manager
S. Mazumdar, Asst Manager (Food Services)
B.R. Revathi Rao, Asst Manager (Housing)
D.V. Subba Rao, Asst Manager (Warehouse)

Physical Plant Services

V.P. McGough, Manager
P.M. Menon, Asst Manager (Admn) (until Feb)
Sudhir Rakhra, Chief Engineer (Civil)
D. Subramaniam, Chief Engineer (Electrical)
C.K. Belliappa, Asst Manager (Workshop)
S.K.V.K. Chari, Sr Engineer (Electronics and
Instrumentation) (on study leave)
N.S.S. Prasad, Sr Engineer
(Electronics and Instrumentation)
A.R. Das Gupta, Sr Engineer (Communication)
D.C. Raizada, Sr Engineer (Airconditioning)
D.V.S. Verma, Engineer (Machineshop) (until Feb)
R. Thiyagarajan, Engineer (Automobiles)
A.N. Singh, Engineer (Heavy Equipment and Tractors)
S.W. Quadar, Engineer (Office Equipment)
K.R.C. Bose, Engineer (Civil)
S.P. Jaya Kumar, Adm Officer (from Aug)

Farm Development and Operations

S.N. Kapoor, Acting Farm Manager
S.K. Pal, Sr Plant Protection Officer
K. Ravindranath, Sr Engineer (Farm Machinery)
M. Prabhakar Reddy, Sr Agricultural Officer
N.V. Subba Reddy, Sr Horticulture Officer
M.C. Ranganatha Rao, Sr Engineer
S. Abid Ali Khan, Agricultural Officer
C. Rama Reddy, Agricultural Officer
Akbar Pasha, Engineer
K. Santhanam, Asst Manager (Admn) (until Aug)
T.A. Krishnamurthi, Sr Adm Officer (from Aug)

West Africa Programs

ICRISAT Sahelian Center, Niger

C.R. Jackson, Director ISC (until Mar)
R.W. Gibbons, Executive Director, West African Programs and Director ISC (from May)
K.F. Nwanze, Principal Millet Entomologist (on sabbatic until Oct)
C. Renard, Principal Agronomist and Team Leader, Resource Management Program
K. Anand Kumar, Principal Millet Breeder and Team Leader, Millet Improvement Program
S.O. Okiror, Principal Millet Breeder/Regional Trials Officer
B.B. Singh, Principal Millet Breeder (Maradi) (until Mar)
J. Werder, Principal Millet Pathologist
M.V.K. Sivakumar, Principal Agroclimatologist
D.C.S. Spencer, Principal Economist (until May)
M.C. Klaij, Principal Soil and Water Management Scientist
C.A. Giroux, French Writer/Editor
B.D. Marvaldi, Project Development Officer
P.G. Serafini, Research Farm Manager
D.C. Goodman Jr., Regional Adm Officer
L.K. Fussell, Principal Millet Agronomist (on sabbatic from Oct)
B. Ndunguru, Principal Groundnut Agronomist (from Sep)
B. Gilliver, Principal Statistician (from Nov)
A. Bationo, Principal Soil Chemist (ICRISAT/IFDC)
Maimouna S. Dicko, Principal Animal Nutritionist (ICRISAT/ILCA) (on sabbatic from Apr)
B.R. N'tare, Principal Cowpea Breeder/Agronomist (ICRISAT/IITA)
L. Marchais, Principal Geneticist (ORSTOM)
S. Tostain, Principal Geneticist (ORSTOM)
A. Tekete, Principal Agronomist (University of Hohenheim)
T.J. Stomph, Sr Research Asst
P. Ouedraogo, Sr Research Asst
Solange Delanne, Executive Asst, Liaison
K.A. Moussa, Personel and Transport Officer
I.J. Cachalo, Bilingual Secretary
G. Ouoba, Computer Programmer
P. Koudogbo, Chief Mechanic

Burkina Faso

C.M. Pattanayak, Principal Sorghum Breeder and SAFGRAD/ICRISAT Coordinator
K.V. Ramaiah, Principal Cereal Breeder—*Striga* (on sabbatic until Aug)
S.N. Lohani, Principal Millet Breeder
P.J. Matlon, Principal Production Economist (until Aug)
M.D. Thomas, Principal Sorghum Pathologist
D.S. Murty, Principal Sorghum Breeder (from Jul)
S. Lingani, Adm Asst, Accounts
B. Ouedraogo, Adm Asst, General Services

Mali

J.F. Scheuring, Principal Cereals Breeder (until May)
S.V.R. Shetty, Principal Agronomist and Team Leader
N.F. Beninati, Principal Sorghum Breeder (from Nov)
S. Touré, Adm Asst
I. Kassambara, Research Associate (Sotuba)
A. Coulibaly, Research Associate (Cinzana)

Southern Africa Programs

SADCC Regional Sorghum and Millet Improvement Program, Zimbabwe

L.R. House, Executive Director, Southern Africa (from Sep) and Project Manager, SADCC/ICRISAT Program
W. Williams, Adm Officer (until Jun)
S.P. Ambrose, Regional Adm Officer (from May)
A.B. Obilana, Principal Sorghum Breeder
S.C. Gupta, Principal Millet Breeder
D.S. Bisht, Station Development and Operations Officer
W.A.J. de Milliano, Principal Cereals Pathologist
M. Osmanzai, Principal Cereals Agronomist (from Sep)
K. Leuschner, Principal Cereals Entomologist (from Dec)
F. York, Farm Manager
W.K. Morgan, Asst Adm Officer

Regional Groundnut Improvement Program, Malawi

K.R. Bock, Principal Groundnut Pathologist and Team Leader
S.N. Nigam, Principal Groundnut Breeder (until May)

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Deputy Head, Dept. of Agriculture,
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