ICRISAT Research Highlights 1987

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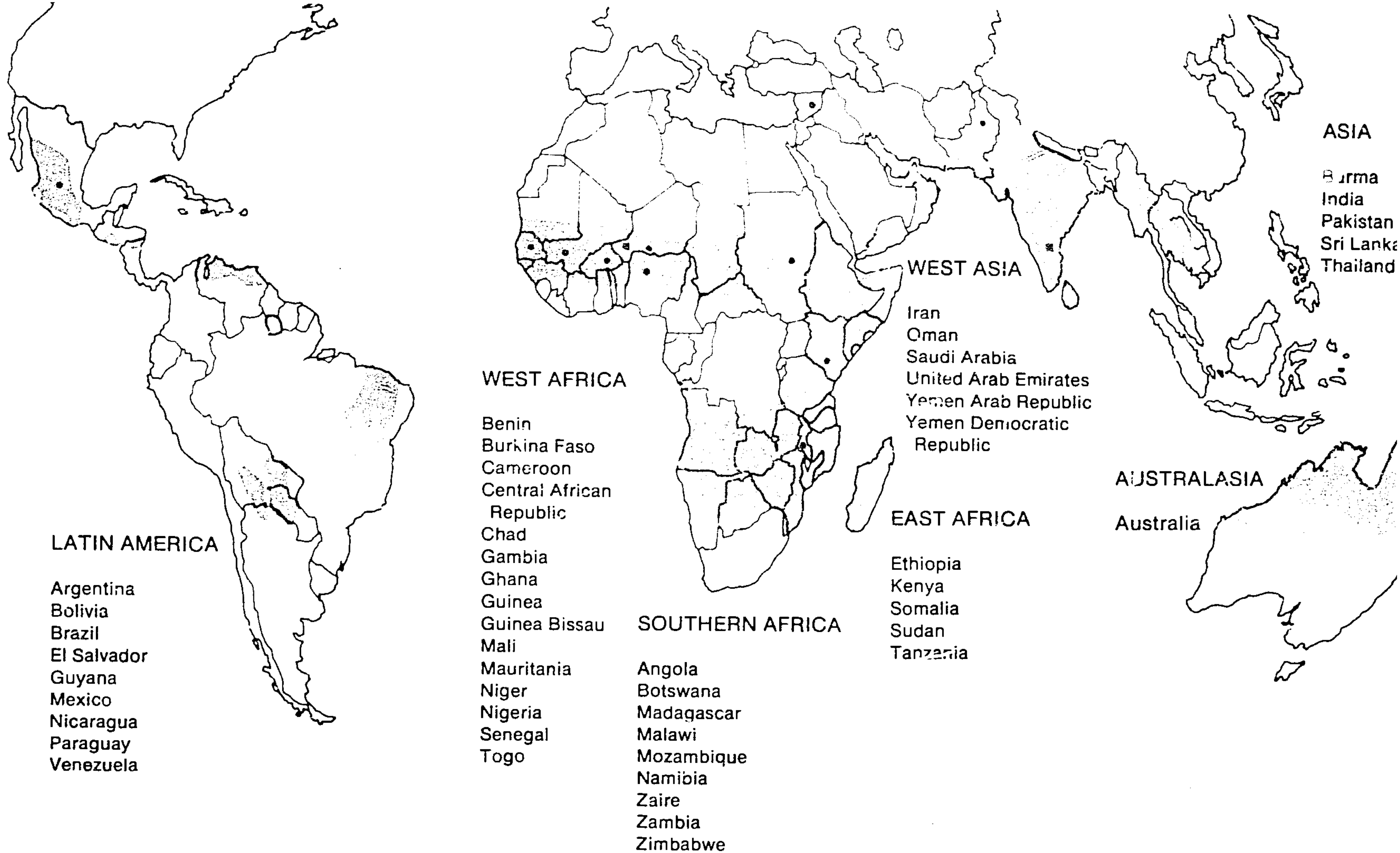


Semi-arid areas (in yellow) covered by ICRISAT's mandate. Green squares indicate location of ICRISAT Center in India and Sahelian Center in Niger; red dots indicate collaborative research stations where ICRISAT scientists have been posted.

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 about 750 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, and Zimbabwe. Scientists were previously posted also in Nigeria and Senegal, but funding for these positions has ceased. A West Africa regional program for sorghum will be initiated in 1988, with two locations: Kano, Nigeria, and Bamako, Mali.

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).

Impact became increasingly visible of ICRISAT's cooperation with national programs, through a network approach that includes regional programs and other international centers. Above, sorghum seed multiplication in Zambia, where advances have occurred through testing and adaptation by the national program of material introduced by ICRISAT from its world collection. Below, visitors viewing an experimental plot growing ICRISAT's pigeonpea ICPL 87 in Rampur, Nepal.

Introduction

ICRISAT moved ahead during 1987 toward meeting its long-term goals.

Cooperation with national programs, through a network approach that includes regional programs and other international agricultural research centers, was considerably strengthened. Impact from such cooperation was readily visible in the Institute's work.

Important progress was made in research on combating the major yield reducers—diseases, insects, and physical stresses— with a view to stabilize and increase farm production of all five crops in ICRISAT's mandate.

Sustainability of agriculture through improved management practices also received attention. From ongoing analysis of village-level data gathered in West Africa, some directions emerged for research and policy decisions.

ICRISAT varieties and hybrids reached farmers' fields in several countries of the semi-arid tropics, while others advanced further in prerelease testing carried out in active cooperation with national programs. The adoption of pearl millet varieties and hybrids in India demonstrates the value of such cooperation.

Training activities expanded worldwide, including those at locations outside ICRISAT Center, and augur well for enhanced transfer of technology.

Advances on all these fronts are outlined on the following pages and described in fuller detail in the 1987 ICRISAT Annual Report.

L.D. Swindale
Director General

Networks and Cooperation

Since its inception 15 years ago, ICRISAT has worked with national programs to establish networks of cooperators throughout Asia, Africa, and Latin America. These cooperators play a vital role in identifying problems, and in testing and adapting genetic materials and farming systems to different agroclimatic regions. They share valuable information with ICRISAT, based on their knowledge of local conditions and their links with farmers. Through such cooperation, solutions often emerge, and ICRISAT is able to play its part in adding to the pool of knowledge already available.

In active partnership with national programs, ICRISAT scientists set up screening nurseries and yield trials, and train people to derive maximum benefit from them. ICRISAT's genetic resources and improved lines, many of which have material from national programs in their lineage, are freely distributed and tested in a wide range of environments along with material from national programs. The release of new varieties in several countries, based upon multilocational testing and local adaptation, emphasizes the close working relationship between ICRISAT and national programs, with the ultimate aim of improving the lot of the farmer in the semi-arid tropics.

Surveys of technology transfer in 1987 indicated that such cooperation yields useful results. All successful public sector releases of pearl millet in India since 1982 combine

A field trip in Malang, Indonesia, during the Peanut Stripe Virus Coordinators' Meeting held there in June 1987. ICRISAT hosted 14 workshops and consultants' meetings during the year.

breeding lines from ICRISAT and the national program. During 1987, ICRISAT's pearl millet hybrid ICMH 451 was widely grown in India and variety ICTP 8203 was being adopted in Maharashtra state. The reaction of farmers from many areas growing these and other ICRISAT-bred material has been favorable; farmers continue to demand and plant these varieties and hybrids. A survey of 24 private seed companies in India showed that all but one received ICRISAT breeding material, and that small firms depend heavily on ICRISAT breeding material for rapid cultivar development.

Another survey, concerned with Vertisol technology in central India, revealed that farmers more readily accepted those agronomic recommendations where inputs were easily available and benefits immediately visible, such as use of improved seeds and fertilizers. Adoption of the technology expanded dramatically during field trials and farmers became keenly aware of the benefits of double cropping. Recommendations were less readily adopted when they required a long-term commitment to provide inputs or when they offered less tangible benefits, such as with land and water management practices. Other studies suggested that Indian farmers use less nitrogen and more phosphorus than economically warranted in the postrainy season. The problem needs further basic and diagnostic research, which will be done by ICRISAT in collaboration with the national program.

In India, ICRISAT scientists hold a yearly meeting with the Central Research Institute for Dryland Agriculture (CRIDA) to identify and plan collaborative research. One experiment identified the reasons for the severe yield reduction of sorghum, cowpea, and castor bean when they were planted as alley crops with leucaena hedgerows. In the semi-

Scientists scoring for foliar disease resistance in a groundnut field in Nawalpur, Nepal, one of the countries for which yearly work plans have been developed.

Surveying insect incidence and damage in groundnut fields during a field trip in Thailand.

arid tropical environment, where water is the major limiting factor, the shallow-rooting leucaena exploits the water which would otherwise support the annual crop. Introducing a shallow root barrier experimentally between the leucaena and the annual crops almost completely removed the adverse effects of competition, but it reduced growth of leucaena.

The implications of this experiment are that in the semi-arid tropics, a deeper-rooting tree—such as *Acacia albida*—(see also p.31) would be more suitable for agroforestry than leucaena, and that moderate shading does not necessarily reduce the yield of annual crops. Many ICRISAT studies have shown the value of fodder and firewood from trees grown as hedgerows with annual crops; farmers usually value the fodder more highly than the firewood.

Collaboration and cooperation with national programs in Africa is increasing, as emphasis shifts toward regional work outside India. The SADCC/ICRISAT sorghum and millet improvement program, with headquarters in Zimbabwe, is helping the Malawi national program multiply breeder seed of two sorghum varieties for possible release to farmers in that country. Three white-grained sorghums and two red-grained sorghums, all introduced in cooperation with the national program, have been selected for prerelease advanced trials in Swaziland. Similarly, the Zambian national program has advanced and multiplied several sorghum and pearl millet lines originally introduced by the SADCC/ICRISAT regional program, and two such lines have been approved for release to

A farm family in Ethiopia, where chickpea surveys were carried out in cooperation with the national program.

farmers. Several such improved pearl millet lines are also in advanced stages of prerelease testing in Botswana, Malawi, Tanzania, and Zimbabwe.

In Zimbabwe, the national program used ICRISAT's simplified inoculation technique to establish a successful nursery to screen for sorghum downy mildew resistance. And two introductions found promising in Mozambique were included in the national seed multiplication program.

The forage program in southern Africa is expanding because interest from most of the SADCC countries is high. Trials and nurseries of forage sorghum and millet were organized, and seed of selected entries was increased. The SADCC/ICRISAT program has introduced 179 forage entries, including cereal grasses and legumes, for seed increase and distribution in the region.

In the first season of a collaborative operational-scale experiment between INRAN (Institut national de recherches agronomiques du Niger) and ICRISAT at Birni N'Konni, scientists from the national program and the ICRISAT Sahelian Center (ISC) studied combinations of cultural techniques such as use of P fertilizer, improved varieties of pearl millet and cowpea in pure crop systems, and use of animal traction for presowing ridging and mechanized weeding. Results from the studies are being used to improve crop and resource management.

In response to a request from INRAN to assist in monitoring the spatial variability of rainfall in Niger, scientists at ISC evaluated the type of rain-gauge network needed at five principal INRAN research stations in

A chickpea breeders' meeting at ICRISAT Center. Such meetings help exchange plant materials and develop plans for cooperative research.

Niger. A network of rain gauges was installed at each station on a 200 × 200 m grid. Also in cooperation with INRAN, automatic weather stations were installed at Bengou and Maradi. Climatic data collected hourly were used to generate monthly weather summaries, which were supplied to INRAN routinely.

ICRISAT held 14 workshops and consultants' group meetings in 1987. Through such meetings and workshops, cooperation between scientists develops, and active networks are fostered. A pigeonpea scientists' meeting was organized by ICRISAT at Nairobi, Kenya, the first such meeting outside India. Participants from ICRISAT and several pigeonpea-growing countries in Africa discussed their research and future approaches to enhance and stabilize production. Participants urged ICRISAT to collect data on cultivated area, production, agroclimatology, constraints, and marketing of pigeonpea in Ethiopia, Kenya, Malawi, Tanzania, and Zimbabwe. They also urged Kenyan pigeonpea researchers and ICRISAT to jointly undertake a varietal improvement program for eastern, central, and southern Africa.

A Peanut Stripe Virus Coordinators' Meeting was organized in Malang, Indonesia, in June 1987. The scattered information on this disease was collated, and plans for future research on the virus were formulated. The Asian Grain Legumes Network (AGLN) has been given responsibility for coordinating these activities. Workshops on integrated pest management of legume pests were conducted in Thailand and Indonesia, in collaboration with the Australian Center for International Agricultural Research (ACIAR). At an AGLN chickpea coordinators meeting, participants from four South Asian countries discussed and developed a regional work plan for chickpea improvement. Meetings with national scientists in Bangladesh, Burma, Nepal, Pakistan, and Sri Lanka were held to develop yearly work plans for each country.

An International Workshop on Biotechnology at ICRISAT Center discussed the potential of biotechnology—both immediate and long-term—to stabilize and increase crop production and to improve nutritional quality. During the workshop, 20 scientists from nine countries examined the feasibility of using biotechnology to improve grain quality, yield potential, yield stability, and utilization of ICRISAT's five mandate crops. The participants recommended that ICRISAT consider using biotechnology only where traditional breeding methods have failed, and avoiding techniques whose benefits are not already proven; setting up cooperative links with specialized institutes, establishing adequate support facilities, and focusing on those aspects of research for which expertise is available at ICRISAT.

In Malawi, the Consultative Group on Groundnut Rosette Virus Disease met for the third time since 1983. The meeting enabled scientists from outside Africa to see plants in farmers' fields that are affected by the rosette disease, and to observe ongoing research of the ICRISAT Regional Groundnut Program for Southern Africa at Chitedze Agricultural Research Station. The 18 participants were provided with seeds of several rosette-resistant breeding lines, and they agreed to continue collaborative research on resistance breeding and on vector ecology, with a view to developing effective disease-management systems.

Among other subjects considered in 1987 workshops and meetings were: soil, water, and crop management in the Sudano-Sahelian zone; groundnut modeling; Vertisol management in Africa; sorghum stem borers, and aflatoxin contamination of groundnut. Each meeting developed recommendations for research, and most agreed on agendas for collaborative studies.

ICRISAT will continue to host and sponsor meetings and workshops with its collaborators from national programs and other international organizations. The synergism generated by interaction at these gatherings has a strong payoff for agricultural research.

Farmers display their groundnut crop in Indonesia.

Responding to Requests

As part of ongoing collaboration with national programs in the semi-arid tropics, ICRISAT often responds to specific governmental requests.

India is the largest producer of groundnut, the most important oilseed crop in the developing world. But despite the magnitude of its production, India is currently facing a serious shortage of indigenous vegetable oils, thus incurring a huge import bill that must be paid in foreign currency. At the request of India's Ministry of Agriculture, ICRISAT hosted a workshop for government officials from the Ministry and six major groundnut-producing states. ICRISAT scientists and the government officials conferred on problems in groundnut production, and on measures to stabilize and boost yields.

At ICRISAT, a package of agronomic practices has been designed that has routinely achieved pod yields of 4-6 t/ha on the Institute's research fields during the postrainy season, compared with the farmers' average of 1.5 t/ha. Workshop participants agreed to demonstrate the ICRISAT package on government farms, and if necessary, modify the package for local growing conditions. The demonstrations were carried out at two locations in each of the six states.

As a result of this workshop, 35 agricultural scientists from the Departments of Agriculture of the six states attended a short training course at ICRISAT Center on the transfer of groundnut production technology. Those who attended were to be responsible for the day-to-day supervision of demonstration plots in their states, supported by technical advice from ICRISAT scientists.

An offshoot of these meetings with Indian officials was the establishment of a new unit at ICRISAT, Legumes On-Farm Testing and Nursery Unit (LEGOFTEN). This multidisciplinary unit is working with Indian scientists to compare the methods that the states, local farmers, and ICRISAT use for growing legumes. LEGOFTEN has thus far concentrated on rainy-season groundnut, but it will also conduct on-farm testing of elite material of all three legumes on ICRISAT's mandate, identify lines for advanced trials, and monitor all-India trials that contain ICRISAT legume materials.

In response to a request from the Lab-to-Land Programme of the Indian Council of Agricultural Research (ICAR), 25 agricultural scientists and extension officials from ICAR, Andhra Pradesh Agricultural University, and the Andhra Pradesh State Department of Agriculture met with ICRISAT scientists to explore ways to improve postrainy-season (summer) groundnut production in the state.

The one-day meeting was held after scientists had identified various agronomic practices used by selected farmers, as well as their problems. ICRISAT offered to supply improved genetic material, including seed of ICGS 11, to demonstrate ultra-low volume sprayers and rhizobial inoculation techniques in farmers' fields, and to work with extension personnel on transfer of improved technologies.

This year, ICRISAT distributed over 50 000 germplasm samples to scientists outside the Institute, but in addition, transferred to Botswana and Malawi the entire sorghum germplasm collected by ICRISAT germplasm botanists from those countries. Although a set of the original germplasm collected in those countries was already left with them at the time of collection, the Institute was pleased to be able to replenish their germplasm stocks from the world collection held in the gene bank at ICRISAT Center.

In response to a request from the SADCC (Southern African Development Coordination Conference) for more help in solving groundnut insect pest problems in the region, an entomologist from ICRISAT Center was based at the Regional Program in Malawi for the 1986/87 season. The entomologist surveyed farmers' fields for an indication of which insects were likely to cause problems (described later in this publication), and worked with national programs on experiments to determine the effects of insect pests on groundnut yields.

During 1986/87, 500 accessions of large-seeded, long-duration pigeonpeas were characterized in collaboration with the National Dryland Farming Research Centre (NDFRC), at the request of the Kenyan government. Scientists identified 63 accessions at Katumani and 51 at Koboko with desirable agronomic traits and local adaptation. The breeders at NDFRC are evaluating the yield potential of these accessions in replicated trials at many locations in Kenya, while the agronomists have included several lines producing high biomass in their 1987/88 trials.

Surveying groundnut and pigeonpea fields in Tanzania was part of ICRISAT s response to a request from the SADCC.

Scientists and agricultural officials from six Indian states attend a short training course at ICRISAT Center, relating to the transfer of improved technology for groundnut production.

Plucking pods after harvest at Garikapadu, Andhra Pradesh, one of the locations in India where cooperative groundnut trials were carried out.

A bumper groundnut harvest near Kurnool, Andhra Pradesh. Boosting yields through improved technology was the ultimate aim of trials in India jointly undertaken by state extension staff and ICRISAT

Overcoming Diseases

Every crop suffers from a number of diseases caused by fungi, bacteria, viruses, and nematodes—all of which reduce yield or quality. At ICRISAT, scientists search for natural sources of resistance in their germplasm and breeding lines, and screen millions of plants every year as part of their work to identify sources of resistance for incorporation into advanced breeding material.

Screening techniques for some diseases developed at ICRISAT provide more flexible and efficient evaluation of pearl millet breeding material than does field screening, and can save one generation in the breeding process.

A mass screening technique was used in 1987 to screen more than a million pearl millet seedlings in the greenhouse for resistance to downy mildew. Seedlings were spray-inoculated at an early stage, and incubated for 12-16 hours at 20°C and under high humidity. The plants were then returned to greenhouse benches, where the frequency of plants showing systemic downy

Symptoms of downy mildew disease in pearl millet.

Mass laboratory screening of pearl millet lines for downy mildew resistance. This technique vastly reduces land and labor resources that would be needed in field screening.

mildew was assessed 10-15 days later. Tests so far indicate that there is a good correlation between greenhouse and nursery plot data.

This screening technique has several advantages over field testing, although screening in a field nursery is essential to confirm downy mildew reaction in advanced materials. The reaction of breeding material to downy mildew can be obtained in less than 3 weeks. Because one greenhouse bay of 50 m^2 substitutes for several hectares of field plots, this technique reduces the resources needed for field screening since land is not necessary, and far less labor is required.

In pearl millet disease research in Africa, more than 200 pearl millet varieties and breeding lines were screened for downy mildew resistance at the INRAN (Institut National de Recherches Agronomiques du Niger) station at Bengou in southern Niger. Sprinkler irrigation was used for the first time to increase disease pressure by providing the ideal conditions for infection. Entries of West African material had a mean downy mildew incidence of less than 10%, while trials of mostly Indian entries had much higher levels of susceptibility. Twelve selections of the wild species, *Pennisetum violaceum*, from Mali and Burkina Faso, did not show resistance to downy mildew in pot trials. A millet variety from Burkina Faso had excellent resistance in all five countries where the West African downy mildew nursery was grown. Multilocational pearl millet testing in India and West Africa clearly demonstrated differences in virulence of the downy mildew pathogen across locations in both regions, and of the rust pathogen in India.

In research on sorghum downy mildew, scientists have now identified the genes that confer resistance to downy mildew. In 1986, 87 F_2 populations, derived from crossing 14 downy mildew resistant parents with each other or with susceptible lines, were screened in India. In 1987, 29 F_2 populations involving eight of the susceptible parents

Symptoms of grain mold, the most important sorghum disease worldwide. Stable sources of resistance have been identified, and these are being used in breeding improved lines.

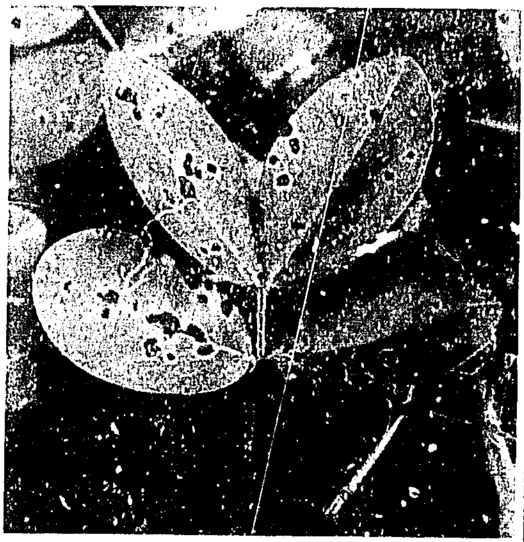
were again screened, with the addition of the backcross F_1 generation for 18 of the populations. A single dominant gene confers resistance in crosses involving IS 2266, while in QL 3 (IS 18757), it appears that at least two genes, and probably modifying genes, confer resistance.

Breeders are using these resistant sources, particularly QL 3 (IS 18757), which has shown stable resistance in 12 years of multilocational testing, to incorporate downy mildew resistance into cultivars with other agronomically desirable characteristics.

Worldwide, grain mold is the most important disease of sorghum, particularly the improved sorghums that ripen before the end of the rainy season when disease pressure is highest. Multilocational trials to test for the stability of grain mold resistance were resumed in 1985 after 156 sorghum lines had been identified as resistant to grain mold. The 1985 International Sorghum Grain Mold Nursery had 114 test entries and three susceptible controls, and was grown at two locations in India, and in Burkina Faso in West Africa. All but six test entries were resistant at the three locations.

On the basis of mold resistance scores and agronomic traits, 31 test entries were retested in 1986 and 1987. In both years, the same 27 test entries were resistant at five locations. Thus in 3 years of testing, resistance in both low- and high-tannin sorghums has proved stable at locations outside India, and breeders are now incorporating this grain mold resistance into white-grained, high yielding sorghums with other desirable traits.

Screening for resistance to early leaf spot of groundnut (*Cercospora arachidicola*) had not been possible at ICRISAT Center because both late leaf spot and rust dominated. Collaborative trials were planned in



Early leaf spot of groundnut: extensive field screening for this disease became possible for the first time at ICRISAT Center.

1987 with the G. B. Pant University of Agriculture and Technology, Pantnagar, Uttar Pradesh, in northern India, where early leaf spot is commonly severe. This initiative coincided with an unusually severe attack of early leaf spot at ICRISAT Center during the 1987 rainy season, and only late and light attacks by rust and late leaf spot.

Thus it was possible for the first time to extensively screen groundnut germplasm and breeding lines for resistance to early leaf spot at ICRISAT Center. Thirty-six germplasm lines showed resistance to early leaf spot, while 22 interspecific hybrids were identified as having resistance to this disease, and eight of them also had significant resistance to rust and late leaf spot diseases. The wild species used as parents included *A. chacoense*, *A. cardenasii*, *A. villosa*, and the amphidiploid *A. correntina* × *A. batizocoi*.

Sources of tolerance to tomato spotted wilt virus (TSWV) in groundnut have also been identified for the first time. TSWV is the causal agent of bud necrosis disease (BND). Until now, the only source of resistance was that some groundnut cultivars were less attractive to thrips, the insect vector that carries TSWV. In laboratory trials, several high-yielding germplasm and breeding lines with resistance to the thrips vector of BND were tested for resistance to TSWV, and two showed tolerance.

Preliminary experiments with different Indian isolates of the pigeonpea wilt pathogen, *Fusarium udum*, indicated the existence of physiologic races. In multilocational trials for fusarium wilt resistance, some pigeonpea genotypes were resistant at one location, but they were susceptible at other locations. To establish whether this variation in the genotypic reaction was due to physiologic races of *F. udum*, the 7-day-old roots of 27 pigeonpea genotypes, raised in sterilized sand in a greenhouse, were dipped in the spore suspension of the fungus and transplanted to pots containing sterilized sand and Vertisol. Wilt incidence was recorded 90 days after transplanting.

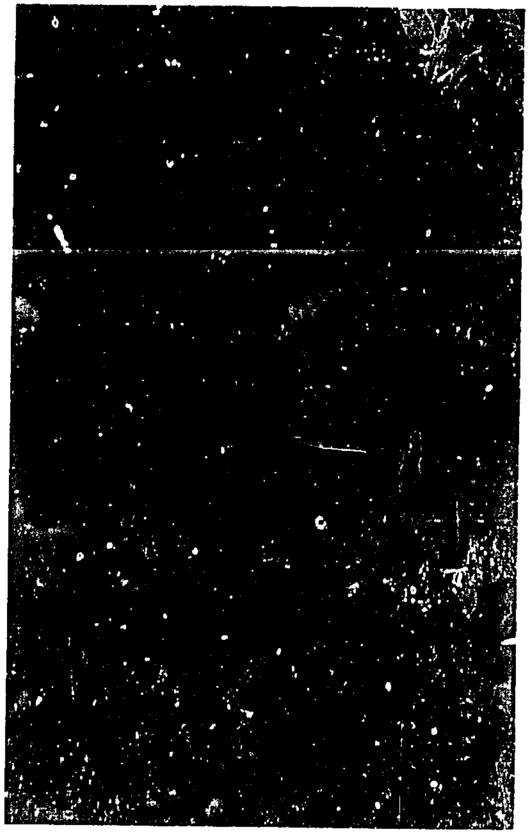
Groundnut lines resistant (left) and susceptible (right) to the tomato spotted wilt virus, which causes the bud necrosis disease (inset shows symptoms).

Based on the reaction of six of the 27 genotypes used in the experiment, the six isolates were grouped into five different physiologic races. The reaction of the six genotypes to both isolates from ICRISAT Center was similar, but they reacted differently to the other four isolates. Studies using other isolates of *F. udum* are in progress.

This work has important implications for multilocational testing of pigeonpea for resistance to wilt.

Surveys conducted in India and Nepal showed that alternaria blight is the most predominant leafspot blight pathogen affecting pigeonpea. The disease had been considered important only in pigeonpeas cultivated during the postrainy season, but the survey revealed that alternaria blight is becoming important even for the rainy-season crop. Several sources of resistance are available, and breeders will work to incorporate them in lines with good agronomic background.

In research on another disease that limits pigeonpea production, sterility mosaic disease and its mite vector, *Aceria cajani*, were found to survive through the offseason (summer months) on ratooned pigeonpea in eastern Uttar Pradesh. It was not previously known how the disease survived in the offseason. A long-duration pigeonpea, ICPL 366, which is resistant to sterility mosaic disease, was selected for on-farm trials in endemic areas of two Indian states.



Field screening for resistance to sterility mosaic disease in pigeonpea (below). At right, the disease symptoms.

Combating Insects

An important part of ICRISAT's effort to stabilize agricultural production is improving the ability of its mandate crops to resist insects that ravage them and drastically reduce their yields of grain and fodder.

Entomologists work closely with breeders and other scientists on interdisciplinary teams to identify insect resistance in wild 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. Along with breeding for natural resistance, ICRISAT emphasizes integrated pest management, including pest surveys, population monitoring, biological control, safer and more efficient methods of pesticide application, and improved agronomic practices.

Insect pests such as shoot fly, stem borer, sorghum midge, head b[illegible] and head caterpillars all limit yields of [illegible]ghum, which is the third most important cereal in India after rice and wheat. Grain yields on farms are low (500-800 kg/ha) although the potential yield is over 5000 kg/ha. Yield losses of 15-20% in sorghum have been attributed to insect pests.

Shoot fly (*Atherigona soccata*) infestation is positively associated with leaf surface moisture and moisture accumulation in the spindle leaf. A resistant genotype, IS 18551, has been identified; it had 25-30% deadhearts after infestation, compared to 95-100% in the susceptible control, CSH 1.

Several sorghum genotypes have shown low susceptibility to stem borer (*Chilo partellus*) attack. Tolerance to attack by stem borer is associated with early panicle initiation and rapid elongation of internodes.

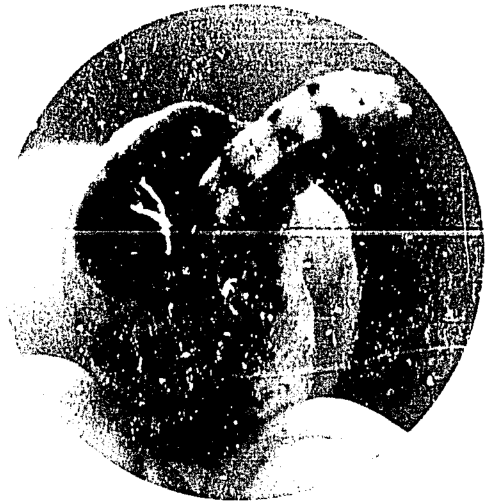
In trials at ICRISAT Center, genotypes have been identified with resistance to both shoot fly and stem borer. The best are IS 2205, IS 5604, and IS 18551. This is an example of breeding and screening to combine resistance to multiple pests in cultivars that are high yielding and have other desirable agronomic traits.

Using a no-choice, headcage technique for testing, acceptable sorghum midge (*Contarinia sorghicola*) resistance has been

Using a stem cage in efforts to study stem borer damage under induced infestation. Several genotypes with low susceptibility to attack by this insect have been identified.

identified in seven ICRISAT lines. In multilocational testing in West Africa, midge resistance was confirmed in four lines that also have high yield potential and good adaptation, including resistance to leaf diseases. Regardless of infestation level, these four ICRISAT genotypes supported significantly fewer head bugs than the susceptible control, CSH 1, and three of these genotypes germinated under heat and drought stress at more than 80%, compared with 43% in CSH 1.

In research to control insect pests of pearl millet at ISC in Niger, scientists found a high correlation between the number of exit holes and the larval population of the stem borer (*Acigona ignefusalis*) in pearl millet. Sampling for stem borer larvae consumes time and labor, and it precludes screening large numbers of millet lines to find resistant sources; however, recording exit holes gives the necessary precision for use in a screening program. Another advantage of this technique is that the stems need not be examined during the growing season, because the exit holes can be counted on the dry stems at any time. This method provides an accurate means of assessing total larval populations attacking a genotype.



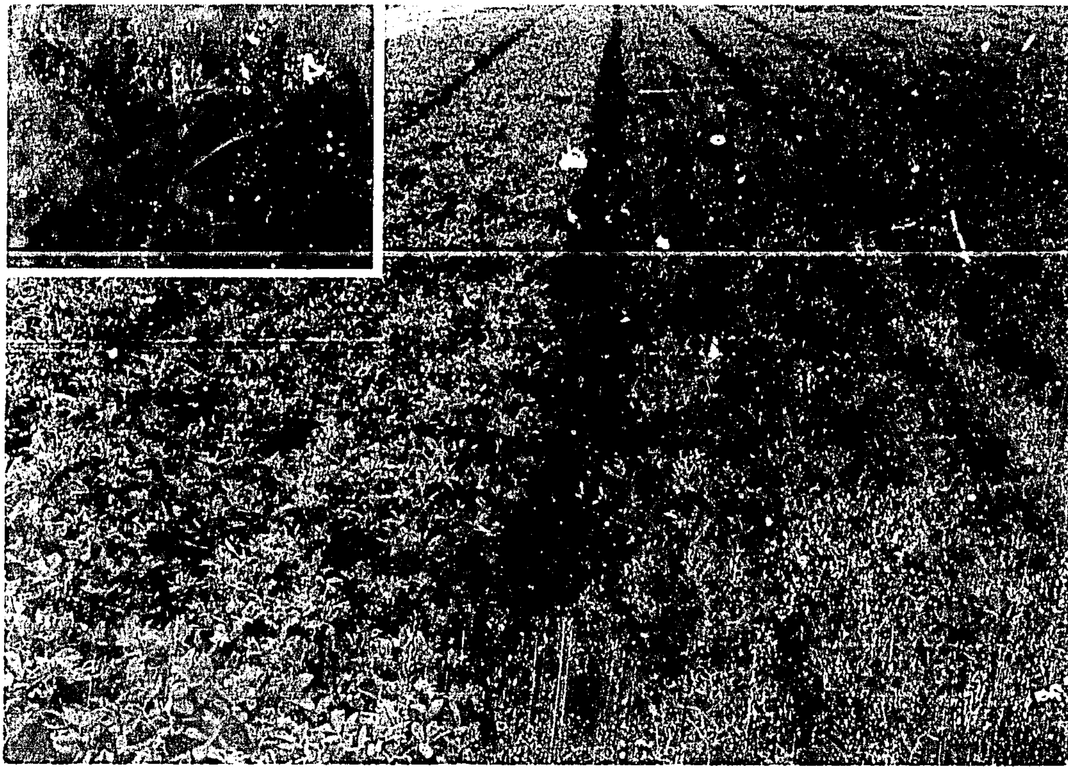
A caterpillar, Spodoptora lituralis, *feeding on groundnut pod.*

A midge-resistant sorghum seen growing well. Its resistance was confirmed, using induced insect pressure.

Also at ISC, studies on crop losses caused by the millet head worm *Heliocheilus (Raghuva) albipunctella* showed that 3-4 larvae per head (a normal larval density on susceptible local cultivars) resulted in a 20% yield loss, and that one larvae resulted in a 6.6% loss per head. This information can be used to estimate losses in farmers' fields.

By screening breeding material in India, scientists identified 25 lines with resistance to groundnut leaf miner (*Aproaerema modicella*) under high-intensity attack.

An extensive survey of groundnut fields in southern Africa, undertaken at the request of SADCC national programs, showed that soil-borne insects, especially termites and white grubs, can cause substantial damage. White grubs (larva of scarabaeid beetles) were the most frequently encountered soil insect.



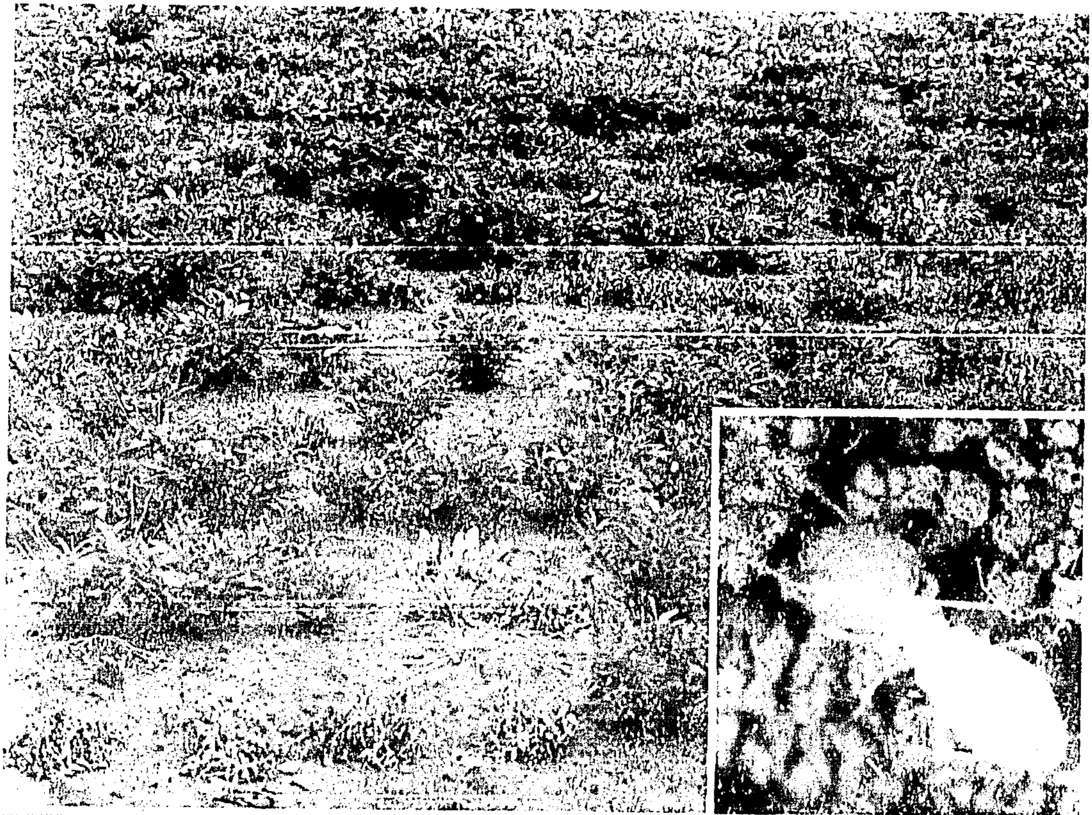
Screening for resistance to leaf miner in groundnut: resistant line can be seen at left, and susceptible one at right. Inset shows insect damage.

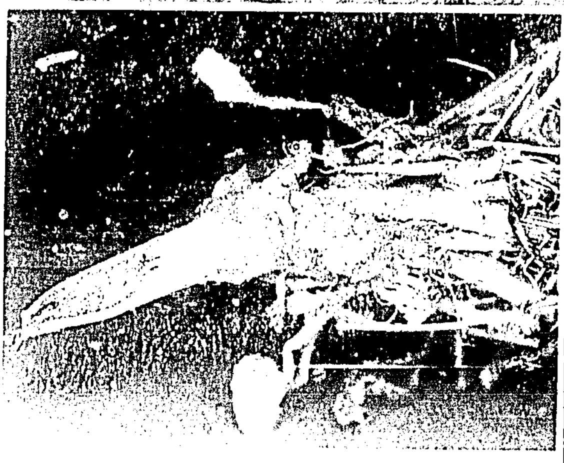
They were particularly numerous in Zimbabwe, where they had damaged the roots of nearly 30% of the plants sampled. *Microtermes* were most abundant in southern Zambia in midseason. In Botswana, estimates from field stations indicated that members of this genus can cause a 50% crop loss by killing plants and damaging pods. Risk of aflatoxin contamination is increased by pod damage.

Some of the observations made during this survey, which will be useful to guide future research, are:

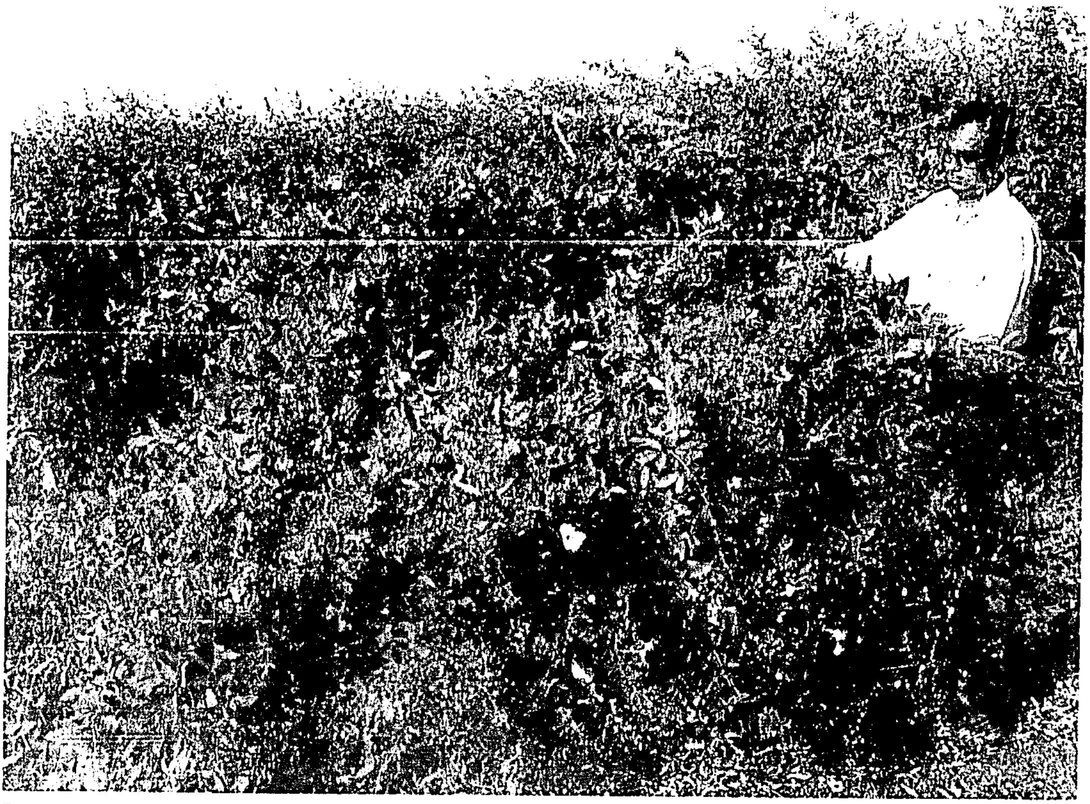
- Soil insects, as a whole, are a major constraint to groundnut production in southern Africa.
- Termites (*Microtermes* spp) attack groundnut plants during a drought because there is little else left for them to eat.
- Killing some ant species with insecticides can increase termite attacks.
- The amount of damage caused by soil insects is related to the intensity of cultivation. Insect damage was less of a problem in fields coming out of fallow and in shifting agriculture than in the intensive agricultural scene of central Malawi and the Zimbabwe communal lands.
- Soil insects are of widely diverse species, especially the white grubs and termites.

In another step in ICRISAT's continuing research on *Heliothis*, scientists have successfully incorporated tolerance/resistance to this insect pest in medium-duration





Soil insects, as a group, were found to be a major constraint to groundnut production in southern Africa. Termites (inset, top right) can cause considerable damage in groundnut fields (top) by eating into the roots (above). White grub (right) is another damaging soil insect frequently encountered in the region. It damages the roots as well.



This pigeonpea line, ICPL 87089, is one of the two medium-duration lines identified that showed resistance to the pod borer, Heliothis armigera, *a devastating insect on both chickpea and pigeonpea.*

pigeonpea. Two resistant lines, ICPL 87088 and ICPL 87089, showed significantly higher yield and less pod borer damage than a control cultivar under pesticide-free conditions.

Larva of the pod borer, *Heliothis armigera*, appear to be developing resistance to the commonly used insecticides in southern India. This emphasizes the value and urgency of screening and breeding *Heliothis*-resistant chickpeas and pigeonpeas. Cooperation with the Overseas Development Natural Resources Institute (UK) revealed considerable dispersal potential in *Heliothis* moths—they can travel up to 90 km in a single night. The pheromone trap network also increased understanding of the population fluctuations across the subcontinent.

The results from International Chickpea *Heliothis* Resistance Nurseries were encouraging, and further progress was made in the selection of chickpeas that combined resistance to *Heliothis* and fusarium wilt. Collaborative studies with the Max-Planck Institute for Biochemistry at Munich identified four volatile chemicals in seeds of susceptible chickpea cultivars that attracted *Heliothis* larvae and egg-laying moths. This development may increase progress in *Heliothis* management by allowing scientists to screen for the presence of these chemicals in searching for *Heliothis*-resistant cultivars.

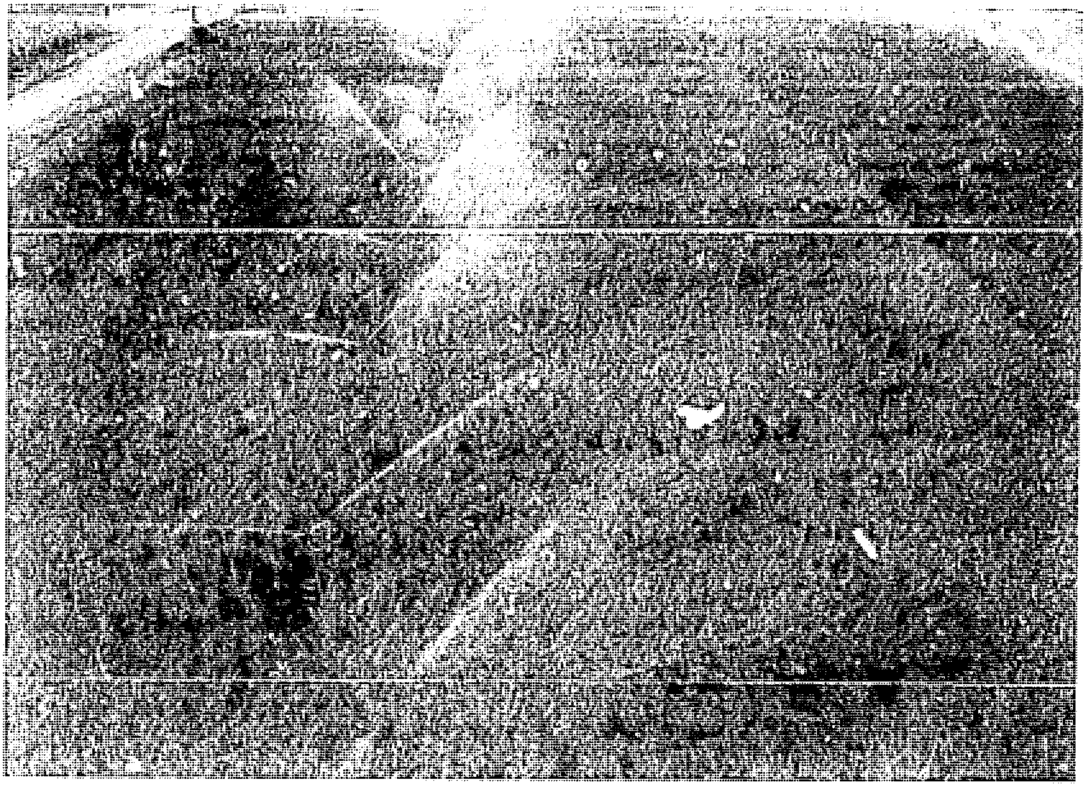
Enduring Physical Stresses

Physical stresses such as high soil and air temperatures, poor soils, sandstorms, saline soil, and highly variable rainfall, adversely affect crop production. ICRISAT scientists join scientists from national programs in studying crop behavior under these conditions.

Scientists often need to study in detail factors that cause such stresses, as well as interactions among them, so as to design measures that can mitigate the stresses. They then try to identify practices, crops, and genotypes better adapted to endure the harsh environmental stresses of the semi-arid tropics.

Routine screening of pearl millet lines from the breeding program for their ability to establish in dry weather began in 1987 at ISC. Genotypic differences for seedling survival under drought were observed. The influence

Differences were observed in both sorghum (seen below) and pearl millet lines for their ability to emerge through crusted soil. Scientists are now studying the mechanism of such emergence in further efforts at crop improvement.



Screening for drought tolerance in pigeonpea using a line-source sprinkler to create graded stress.

of seed quality on seedling survival is being investigated further. Seedlings survived better under a combination of high soil tempera-tures (more than 60°C at the soil surface) and adequate seedbed moisture, than they did under a combination of dry seedbed and high soil temperatures, or on a dry seedbed.

In work at ICRISAT Center, cereals researchers found that the ability of some seedlings to emerge through a soil crust that inhibited emergence of other seedlings may be genetically controlled.

Beginning in 1981, a large number of materials was identified by using the same technique year after year. The emergence trait was identified in both sorghum and pearl millet where the same materials were grown from seeds produced in different seasons, or when the same seed lot was grown in different trials or years. If the number of seedlings that emerged through the crust was 60% or more of those emerging in the control (where the crust was mechanically broken), then the cultivar was considered for selection as a crust-tolerant genotype.

ICRISAT physiologists now screen for this character only when breeders request evaluation of their material, but they are also trying to define the mechanism of emergence through the soil crust.

In other pearl millet research, several test hybrids yielded well in initial trials under terminal drought. These hybrids were made with pollinators selected under drought conditions or with early open-pollinated varieties, and with very early male-sterile lines such as ICMA 2 (843A) and 863A. This approach attempts to combine two traits:

Studying the response of a pigeonpea wild species, Atylosia albicans, *to various levels of soil salinity (control at left, highest level of salinity at extreme right). This work offers promise for incorporating enhanced salt tolerance into cultivated pigeonpea.*

earliness from the male-sterile line (drought escape) and tolerance to drought from the pollinator. This combination may help breed hybrids that are genuinely superior under such conditions.

Genotypic differences in moisture response of chickpea and pigeonpea were also confirmed in work at ICRISAT Center. In chickpea, biomass and seed yield of all genotypes not affected by disease, grown over two seasons, increased linearly with soil moisture up to a level where the surface soil was maintained at or near field capacity. This linearity over a wide range of soil moisture levels further simplifies research, because it validates the use of just two moisture levels (with and without irrigation)—instead of using the line-source irrigation system—to compare chickpea genotypes for drought response.

A major problem of vigorously growing chickpea crops is excessive production of vegetative biomass. In areas where night temperatures fall below 8°C during flowering, such as in northern India, pods often fail to set. Failure to set pods also encourages excessive vegetative growth, resulting in a low harvest index. Researchers have now created 12 populations of cold tolerant material that begins to flower and set pods during the coldest part of the year. Preliminary data suggest that it is possible to increase yield by advancing flowering and pod set into the cooler months. These genotypes produced a greater proportion of seed in their biomass.

Short-duration pigeonpea can face intermittent drought stress during the rainy season. During the 1986 rainy season, 30 short-duration genotypes were screened for their response to a moisture gradient, created by line-source sprinklers. Irrigation was applied during September when rainfall was sparse, corresponding to the postflowering period for most genotypes. Responses to the different moisture levels were diverse. In some cases, both growth and yield were depressed at the highest moisture levels, which indicated effects from waterlogging. This suggests that the line-source sprinkler system could be used to screen simultaneously for both drought and waterlogging tolerance.

Yield potential of extra short-duration pigeonpea genotypes was evaluated in peninsular India under rainfed conditions. In a season with less than average rainfall yields of up to 1.6 t/ha were obtained within 90 days. Such short-duration cultivars would be valuable in environments with a short rainy season.

In some areas where pigeonpea is grown, increasing soil salinity limits production of this important multipurpose crop. In an attempt to find sources of improved salinity tolerance in pigeonpea, 15 wild relatives were grown in sand culture with different salt concentrations, and flushed with a nutrient solution which included nitrogen (plants were not inoculated with *Rhizobium*). Some of the wild species, including *Atylosia platycarpa* and *A. albicans*, possess considerable salt tolerance. This offers promise for incorporating enhanced salt tolerance into cultivated pigeonpea.

A staggered harvesting procedure to select for earliness in groundnut has been improved by legume scientists, using degree days (heat units)—instead of subjective maturity traits—for determining date of harvest. Crops grown in the rainy season take longer to mature, so when harvest times are determined by thermal data rather than by calendar, comparison between harvest data collected in the rainy and postrainy seasons is more precise.

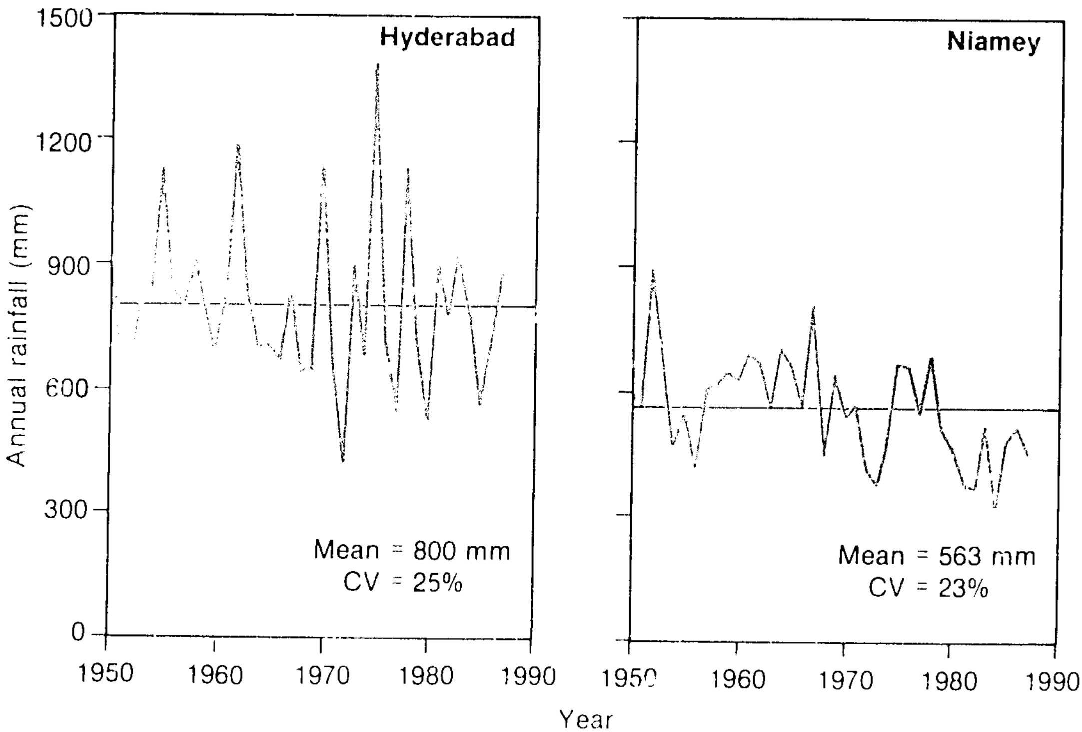
Managing Resources

The farmers of the semi-arid tropics face many hazards: low and unpredictable rainfall, temperatures exceeding 40°C, infertile soils, and in the Sahel, fierce sandstorms. Some of these constraints can be overcome by good management, which is the key to exploiting the limited resources of the SAT in ways which are both efficient and sustainable. ICRISAT scientists, working in India and Niger, seek to find better systems of management which will increase the productivity and income of farm households.

The Sahelian countries of West Africa have recently suffered from extreme droughts and persistent crop failures, while in India, there is a widespread belief that rainfall is becoming more variable. As part of a study to evaluate changes in rainfall variability in India and the Sahel, long-term records for two typical locations, Niamey in Niger and Hyderabad in India, were analyzed for evidence of recent changes.

The analysis of 87 years of rainfall data at Hyderabad showed no significant trend, and the rainfall in a given year was not related to that of the preceding or following year.

At Niamey, annual rainfall was less than the average in 40 of the years from 1905 to



Annual rainfall for 1950-1987 at Hyderabad, India, and Niamey, Niger. This period formed part of the 87-year study of rainfall data.

1987, with a high frequency of dry years during the last two decades. For example, in only 4 of the last 17 years was the recorded annual rainfall greater than the long-term mean, and rainfall in all years after 1979 was below the mean. Serious drought (defined as rainfall less than 75% of the mean) has occurred in 5 of the last 10 years. This decline has shortened the growing season in an already marginal zone, emphasizing the need for short-duration cultivars in the Sahel.

Compared with Hyderabad, Niamey has longer sequences of consecutive 'dry' years with below-average rainfall and much fewer 'wet' years interspersed among the dry years. Thus drought periods are longer in the Sahelian Zone, and the agricultural consequences are more severe than those in the Indian SAT. Developing the know-how to increase and stabilize food production in the Sahel is a formidable challenge.

At the ICRISAT Sahelian Center (ISC), a number of management approaches are being evaluated. In a medium-term soil management experiment, scientists assessed the effects of cultivation methods and crop rotation on yields. During the 1987 rainy season, a pearl millet crop benefited substantially from the residual effect of pure cowpeas, particularly in combination with tillage. Average pearl millet grain yield increased from 542 to 733 kg/ha on cultivated plots. Also, under 430 mm of rainfall, four ICRISAT groundnut cultivars gave yields of 152 to 260 kg/ha when intercropped with millet, and 405 to 450 kg/ha

In agroforestry studies—ongoing in both India and West Africa— Faidherbia albida *(previously known as* Acacia albida*) has been found quite promising, with its spreading habit. In this field, the tree is grown along side crops of castor (foreground) and sorghum (background).*

when grown as a sole crop.

An INRAN/ICRISAT collaborative operational-scale experiment at Birni N'Konni, Niger began in 1987 to study improved cultural techniques. It was a severe test. The first planting rain began 5 weeks late, and up to harvest only 240 mm of rain fell. Applying fertilizer increased millet grain and stover yield over the traditional system of millet and cowpea mixed cropping. Sowing on ridges and mechanized interrow weeding, using animal traction, additionally increased yields of millet grain, stover, and cowpea hay, but reduced cowpea grain. Mechanization reduced time spent on the first weeding by 42% and on the second by 37%.

Scientists at ISC also evaluated the response of 10 groundnut cultivars sown on an Alfisol at Bengou in southern Niger to three different land management treatments: flat, broadbed-and-furrow (BBF), and tied ridges. The BBF and tied-ridge treatments both gave higher yields than flat sowings.

In Niger, there is growing interest in off-season crops to augment rainy-season crops. Scientists have been evaluating the potential of extending cowpea into this period, when the pressure from aphids is either nonexistent or lower than in the rainy season. In preliminary trials, 1 t of grain and 2 t of hay were obtained with either no protection or very limited protection from insect pests. This is an important finding because insecticides are scarce in the region and

Perennial pigeonpea, grown here as an alley crop with sunflower, is being studied for its promise in a range of cropping systems, including its potential in agroforestry.

farmers usually cannot afford them.

Numerous cowpea breeding lines were evaluated at ISC, both as sole crops and as intercrops. Leaf diseases, such as bacterial blight and *Macrophomina*, appeared on large numbers of plants. Scientists identified 12 cultivars that have the ability to stay green until the harvest of pods, an important characteristic for dual-purpose (grain + fodder) cowpeas.

In cowpea yield nurseries, 10 cultivars gave grain yields of 0.70-0.95 t/ha, even though there was no rain from flowering to maturity, temperatures were very high, and the crop received no supplemental irrigation.

Among forage legumes screened for intercropping at ISC, the perennial *Stylosanthes hamata* yielded 2.5 t/ha of fodder in 1987 and 5.3 t/ha in 1986. A cultivar from CIAT yielded more than the others.

Faidherbia albida (previously known as *Acacia albida*) is a large spreading tree that farmers often leave in cropped fields. Its role in agroforestry systems of the Sahel is well documented. Two studies began in 1987 to collect and improve the tree for agroforestry plantings. The first involved monthly visits to 120 trees to determine variation in flushing, flower production, and leaf drop. Most trees followed the characteristic pattern of losing leaves during the first month of the rainy season, but there was a wide, potentially exploitable, variation in this trait. In a second study, seed collected from 49 mother trees

Sorghum responding spectacularly to phosphorus (background) on previously nonfertilized Vertisol. In the foreground is the control treatment, with no added phosphorus.

was sown in a replicated experiment with single-tree plots. At 6 months, there was much more variation within the families than between them. Individual trees showed impressive variation in form and early growth rate, traits that could be exploited and improved genetically. Vegetative propagation through root cuttings of superior individual plants could give rapid gain.

In other agroforestry research, conducted at ICRISAT Center, three perennial pigeonpea varieties yielded far more than *Leucaena leucocephala*. In 18 months, wood production by pigeonpea averaged 20-24 t/ha, compared to only 5-9 t/ha by leucaena. Additional advantages of perennial pigeonpea include pod and fodder production and less competition with intercrops. In India's SAT, alley cropping of leucaena and annual crops is unlikely to be viable because the shallow-rooting leucaena robs moisture from the annual crop. On the other hand, prospects for the expansion of sole-cropped farm forestry systems are good because of the increasing demand for fodder and its cost.

In the 1987 rainy season at ICRISAT Center in India, sorghum responded spectacularly to phosphorus applied to a previously nonfertilized Vertisol with a very low level of available P (less than 0.05 ppm). Grain yield increased from 0.13 to 3.48 t/ha with the addition of 40 kg of phosphorus per ha. In the postrainy season, the lack of response to fertilizer in farmers' fields indicated the need for further research, both basic and diagnostic.

Further field studies on a range of soil types have shown that nodulated chickpea responds to nitrogen fertilizer, at least marginally. This indicates a scope for improvement of the chickpea-*Rhizobium* symbiosis. On the other hand, only small doses of nitrogen severely hindered symbiotic development. Among various crops studied, chickpea had the greatest ability to lower the pH of the root zone. This may explain the ability of chickpea to extract adequate phosphorus from alkaline soils with apparently low levels of available phosphorus.

The growth habit of long-duration pigeonpea has little influence on its performance in an intercrop with millet because the growth period after harvest of millet is long enough to compensate for any competition. Genotypes of pigeonpea suitable for growing as a mixture with black gram (*Vigna mungo*) in rice fallows have also been identified.

Village Studies in West Africa

For 5 years from 1981 ICRISAT researchers gathered data in 10 villages in Burkina Faso and Niger. This effort parallels the Village-Level Studies (VLS) conducted for 10 years in India, which concluded in 1985. ICRISAT's economists studied in detail agroclimatic factors and behavioral responses associated with decisionmaking by farmers. The vast quantity of data assembled in these studies will be used to help refine research goals, and to determine what changes of policy are needed to help farmers increase and stabilize agricultural production.

Two aspects are now ready to be reported: why animal traction has been adopted so slowly and unevenly across different subregions of West Africa, and strategies that farmers use to maintain household consumption during prolonged drought.

Adoption of Animal Traction

The limited extent to which animal traction technology has been adopted in the West African SAT has long puzzled development officials and researchers. Traction systems are employed on less than 15% of the cultivated area sown in the region, despite public and private efforts to promote adoption spanning more than half a century.

ICRISAT researchers collaborated with SAFGRAD (Semi-Arid Food Grains Re-

ICRISAT's village studies in West Africa have traced some reasons for slow adoption of traction technology by farmers.

search and Development) in analyzing production for 1981 and 1982 recorded in Village-Level Studies in Burkina Faso. These data were from four ICRISAT study villages in the Sahelian and Northern Guinean zones, and two villages representing the Sudanian zone monitored by the SAFGRAD program.

The researchers found that particular components of draft animal tillage systems can be used profitably, but only under specific conditions that permit high utilization of animals and equipment. Oxen-drawn plows can substantially increase yields in farmers' fields, primarily in the Northern Guinean zone where the preparatory rainfall period is long enough to permit land preparation without significant delays in sowing. Heavier soils and crops that respond well to plowing —such as maize, groundnuts, and cotton— also helped adoption of mechanized plowing by farmers in that zone.

Even in this favorable environment, the increased yield from plowing was generally too small to make adoption profitable unless farm size was expanded. Because labor for weeding restricts farm size, mechanized weeding to save labor had to accompany plowing where surplus land was available for expansion.

The analysis indicated that in each village the marginal rate of technical substitution between draft animal power and human labor exceeded five. This means that even with three persons required to guide a team of oxen—a practice common in the region— human labor is substantially more productive when working with draft animals than with traditional practices.

In all study sites, the analysis suggests that the maximum benefits cannot be realized until 6 to 8 years after adoption. Before this point, early adopters who bought animals and equipment on credit faced cash-flow imbalances. When their debts were compounded by unfavorable weather and poor harvests, many asset-poor adopters lost money, equipment, and animals.

Animal traction systems display important economies of size. A linear programming model of a small farm was constructed to trace the effects of equipment package, farm size, restricted access to land, and limited utilization of draft animals on profitability. Ox-plow adoption alone was not profitable, because the model predicted no area expansion and use of a draft team for only 60 hours during the growing season. With the adoption of both plowing and weeding equipment, gross farm income increased by 60-70% over manual tillage, and annual equipment use was estimated to increase to more than 400 hours.

When the number of family workers in the model was altered, farm revenues were positively associated with family size. Small farms are at a disadvantage: the labor required to maintain the draft animals demands a larger share of their limited supply, and the small area, which can be sown manually, limits use of the draft animals for both weeding and plowing.

The model also predicted that initial investment in the full oxen package was not recovered until the 5th year, when full benefits were also realized.

The results of this study carry important implications for mechanization policy. Equipment packages should be designed and directed only to areas where rainfall patterns, soil types, and land availability permit high and profitable utilization of each relevant component. Targeting within those areas to larger and better-endowed farmers would make adoption even more successful. Poor targeting underlies many past failures.

Such a policy would favor already privileged producers, but efforts to promote adoption among farmers in marginal areas and among those who lack the resources needed to complement and fully utilize the equipment and animals, will only burden them with untenable investments and financial loss. Such unsuccessful adoption of traction systems among very poor farmers would thus be even more damaging than extension favoring the better endowed.

Income and Consumption During a Drought

Poor rainfall during 1984 severely reduced crop yields in the Sahelian and Sudanian zones of Burkina Faso. ICRISAT's farm-level studies were able to monitor strategies used by drought-affected farmers to maintain household consumption. The International Food Policy Research Institute (IFPRI) collaborated on this project, which enabled researchers to include a 24-hour recall survey of food consumption, conducted at quarterly intervals.

As a result of the drought, household crop production from the 1984 harvest met only 29% of the annual energy requirement in each zone, using the World Health Organization (WHO) standard of 11.9 kilojoules (2850 calories) per day for an adult male. But despite this lower production, the average Sahelian household met its consumption requirements and had a daily intake of more than 12.2 kJ per adult male equivalent. In contrast, actual consumption among Sudanian zone people averaged 18% below the WHO standard.

The consumption analysis showed that asset-poor households in both zones consumed a higher percentage of purchased food and were thus more adversely affected by market inefficiencies. Such vulnerability was particularly acute during the immediate preharvest period, when 60-70% of the energy consumed in the poor strata was purchased. Because grain prices normally peak during this period, the effects of seasonal

Rural households that relied on diversified activity for their income, rather than solely on cropping, were better able to adopt to hardships imposed by recurrent drought in the region. Artisan skills can be a useful source of income.

Small ruminants and adequate storage for years when harvests are better are also part of the overall strategy some farmers successfully use to combat drought.

price swings on real income were acutely felt by poorer households.

The employment and income profiles of sample households were analyzed to determine factors that explain the significantly different consumption patterns in the two study zones. The Sahelian farmers derived their incomes from considerably more diverse sectors and regions than did the Sudanian farmers. For example, crop production (including farm wage labor) accounted for only 23% of income in the Sahel sample, but fully 55% in the Sudanian zone. Major sources of alternative income included livestock trading and migration labor, which together provided nearly two and a half times the absolute income for households in the Sahel compared to those in the Sudanian zone (CFA 17 100 versus CFA 7100 per household).

Since income from both sectors is largely determined by economic conditions in the urban centers of Burkina Faso as well as in the coastal countries of West Africa, earning levels from these sources have relatively low covariation with local crop incomes. These sources of supplemental income, therefore, help stabilize total household income when fluctuations occur in local crop production.

In contrast, farming households in the higher and less variable rainfall conditions of the Sudanian zone, have traditionally emphasized crop production, with somewhat smaller investments in livestock. Increasing land pressure and ecological decline have reduced or eliminated the grazing potential, further reducing the importance of livestock. Land pressure has also reduced the capacity of farmers in the Sudanian zone to produce and stock large grain surpluses as a buffer against annual production fluctuations. Because these changes have occurred rapidly and relatively recently, migration patterns and links with external employment have not yet evolved to replace the insurance role formerly played by animal and cereal stocks.

This study has several implications. First, to determine the magnitude, location, and welfare consequences of crop failures, crop production and food consumption figures need to be broken down by region, household wealth and season. Average regional measures can grossly underestimate the food problem, depending on how consumption is distributed across households and seasons.

Second, measures normally used to assess the relative need for relief assistance among regions, such as yield or rainfall deficits, may poorly reflect the degree of actual food insecurity because there are differences in the structure of production and in farm-level purchasing power. The areas of greatest risk are not necessarily in the low-rainfall Sahel, as is commonly assumed, because income strategies vary regionally. When comparable production shortfalls occur, there may be greater risk of severe food shortages in the Sudanian zone.

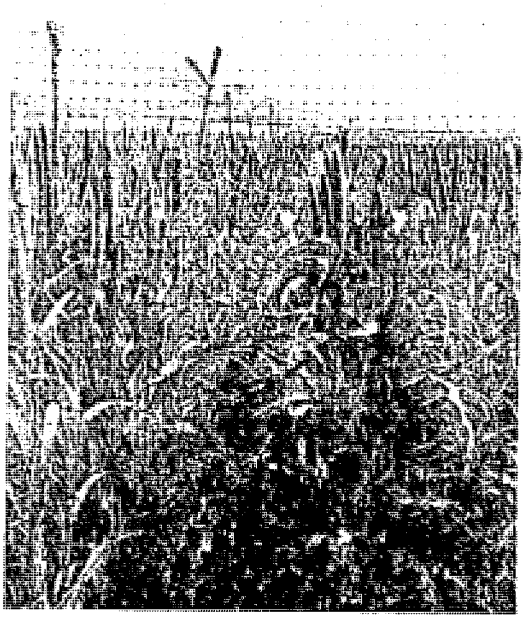
Third, dependence on the market—and vulnerablity to its inefficiencies—was high following a poor harvest at both study sites and across wealth strata. Poorer households depend more strongly on the market in both zones, and purchase more of their total consumption during the preharvest seasons when cereal prices are normally high. Improvements in the market infrastructure to reduce interregional and interseasonal price margins could benefit both efficiency and equity. Where purchasing power is low, generating seasonal employment—by means such as public works projects financed by food-for-work—may be a highly effective and complementary policy.

Pearl Millet in India

Pearl millet, in contrast to other major cereals, is a crop grown with little fertilizer, and virtually no other inputs. Thus the importance of pearl millet to the resource-poor farmer of the more hostile Indian environments cannot be overestimated. In 1982, the Ministry of Agriculture, Government of India, released the ICRISAT open-pollinated variety ICMV 1, as variety WC-C75. It was widely adopted by farmers at a time when the popular hybrid BJ 104 was succumbing to downy mildew, the most devasting disease of pearl millet. This year—1988—will be the fourth consecutive year in which ICMV 1 has been sown on more than 1 million ha.

Despite the availability of ICMV 1, the seed industry was compelled to continue seed production of hybrid BK 560, which is on the same male-sterile line as BJ 104, because there were no other public sector hybrids available for Indian farmers, many of whom have a preference for hybrids. This resulted in higher disease levels in the farmers' fields and seed production plots.

Increase of breeder seed in progress of pearl millet ICMH 451, which has made rapid strides after its release in India in 1986.



A downy mildew resistant hybrid from ICRISAT, ICMH 451, was released in 1986. ICRISAT produced a considerable amount of breeder seed of the parental lines of this hybrid, and by the 1987 rainy season the public and private sector seed agencies in India had produced large quantities of ICMH 451 seed. After only one season, farmers were growing it on over 1 million ha.

The progeny from which the pollinator of this hybrid was derived was first selected by an ICRISAT breeder in Burkina Faso, and sent to ICRISAT Center, India.

ICMH 451 is very high yielding. Over 3 years in AICPMIP (All India Coordinated Pearl Millet Improvement Project) trials it was the highest yielding hybrid, and yielded 30% more grain and 20% more fodder than BJ 104 in the 2 years BJ 104 was in the trial. ICMH 451 has excellent food quality, with the highest protein and lysine content of any pearl millet cultivar. In ICRISAT trials, where its adaptability has been studied, it has given more stable yields across a range of hostile environments than most other entries. It has excellent resistance to downy mildew, and its seed production is problem-free.

The production and release of these high-yielding cultivars, resistant to downy mildew, is highly significant. The average grain production of pearl millet in India exceeds 5 million tonnes annually. At present-day prices of US$ 123/t, the annual value of the crop is about US$ 650 million, excluding the value of the fodder. The marginal value of ICMH 451 and ICMV 1 is tens of millions of dollars annually.

This breeding success has been made possible by ICRISAT's global approach to pearl millet breeding, which has relied substantially on the introduction and exploitation of African germplasm. This approach has significantly broadened the crop's former narrow genetic base in India, and it has introduced considerable variation for resistance to downy mildew. This germplasm and improved breeding lines developed from it should provide a rich source of parental material for further improvements in the future.

Reaching Farmers' Fields

Over the years, ICRISAT's cooperative efforts with national programs have led to the release of many finished varieties and hybrids, often through a process where introduced breeding materials are adapted or developed further within national programs. Outlined here are releases specific to 1987.

In 1987, the workshop of the All India Coordinated Pearl Millet Improvement Program (AICPMIP) recommended three hybrids for release and general cultivation in the country. Two of them combine ICRISAT male-sterile lines as seed parents with pollinators from the Indian national program—HHB 50, from Haryana Agricultural University, and Pusa 23, from the Institute of Agricultural Research, New Delhi. An ICRISAT hybrid, ICMH 423, was the third hybrid to be released.

In southern Africa, one pearl millet variety was released and two advanced to prerelease stage in Zambia.

Sorghum variety ICSV 112 (SPV 475) was recommended for release and general cultivation in India by the All India Coordinated Sorghum Improvement Program (AICSIP) workshop. In more than 200 tests over 6 years, it yielded substantially more than the previously released ICRISAT variety ICSV 1 (CSV 11). Another sorghum, ICSV 145 (SAR 1), resistant to the parasitic weed *Striga asiatica*, was recommended for cultivation in *Striga*-endemic areas of India, excepting the state of Karnataka. In Mexico, ICSV 112 was released as UANL-1-V-187 by the University of Nuevo Leon.

An ICRISAT sorghum variety (ICSV 1), which was yield tested in Ethiopia for several years as (SC 108-3xCS 3541)-19-1, was released there by the Institute of Agricultural Research. In Zambia, the sorghum hybrid WSP 287, based on an ICRISAT-bred female parent, was also released.

The SADCC/ICRISAT sorghum and millet improvement program is helping national programs multiply breeder seed of two sorghum varieties, ICSV 112 and ICSV 1 (SPV 351). Both have been released in Malawi, while the Zimbabwe national program has released ICSV 112 as SV 1 and another ICRISAT line ICSV 88060 (A6460) as SV 2. Three white grained sorghums (ICSV 2, ICSV 112, and ICSV 132) and two red sorghums, introduced in cooperation with the national program, have been selected for prerelease advanced trials in Swaziland.

The Caribbean Agricultural Research and Development Institute in 1987 released ICG 7886 as groundnut cultivar "CARDI-Payne" for cultivation in Jamaica. This germplasm accession had been identified by ICRISAT and the USDA-ARS, Tifton, Georgia, USA, as having a high level of resistance to rust and moderate resistance to late leaf spot.

ICGV 86065, a short-duration groundnut bred at ICRISAT, has been identified for multiplication and large-scale testing in Burma.

ICRISAT groundnut cultivars have performed well in evaluation by the All India Coordinated Oilseeds Research Project (AICORPO). ICGS 44, sown in the western zone, yielded on average 24% more than the local variety.

In the International Foliar Diseases Resistance Trial in Thailand, three ICRISAT groundnut lines yielded over 3.5 t/ha of dried pods, compared with 2.2 t/ha from the local control cultivar. A drought-tolerant variety, ICGV 86635, outyielded local control varieties by 30% at two locations in India, and by 50% in a location in Thailand. In international testing of confectionary groundnuts, per hectare pod yields (in tonnes) were 8.6 for ICGS 85 in Egypt, 3 for ICGS 61 and ICG(CG)S50 in Burundi, and 4 for ICG (CG)S 54 in Sudan and Zambia.

In collaboration with ICARDA, six chickpea cultivars from international nurseries were released in Cyprus, Morocco, Sudan, and Turkey. Iraq and Italy also each released one cultivar. An economic feasibility study, conducted in Syria at nine farms, has shown that sowing chickpeas in the winter instead of waiting until spring can double farmers' income. Bangladesh scientists released the ICRISAT-developed chickpea ICCL 81248 as Nabin for general cultivation in that country. In Nepal, the Varietal Release Committee released chickpea variety ICCV 1 (ICCC 4).

Training Activities

Training agriculturalists from countries of the semi-arid tropics strengthens research capabilities, develops skills, and increases technology transfer to national research and extension programs so that they can play an active role in both evolving and using improved technologies. In addition to the formal training offered at ICRISAT Center, institute scientists posted elsewhere also offer research advice and training.

In 1987, 210 trainees participated in various training programs at ICRISAT Center. For the first time, trainees included agricultural students from Nicaragua, Trinidad, Tunisia, and Vietnam. Thirty-five in-service fellows from 11 countries participated in intensive skills development programs in pathology, entomology, cytogenetics, physiology, plant breeding, and soil fertility. Of the 127 in-service trainees from 35 countries, 89 were trained during the long-term, rainy season in crop improvement, crop production, resource management, library science, biochemistry, physical plant services, and farm development operations.

Postdoctoral participants came from 10 countries to ICRISAT Center. In research on pearl millet, a crop physiologist investigated the relationship of vegetative duration with

In-service trainees being shown how to emasculate sorghum.

In-service trainee from the Philippines harvests chickpea on his experimental plot.

In-service trainees learn about intercropping in studying agronomy.

In-service fellows attending an international training course in legumes pathology, the seventh such course hosted by ICRISAT.

phenotype, while a breeder studied the utility of male-sterile lines selected from diverse cytoplasms. In legumes, a research fellow worked on the inheritance pattern of dry root rot resistance in chickpea. A postdoctoral fellow in resource management completed a year's study on the influence of sorghum plant density on water-use efficiency and yield.

Twenty-five students from 15 universities and 11 countries conducted theses research on a wide range of topics. In chickpea research, one student completed a thesis on generational relationships and the effect of spacing and selection, while another completed a 2-year study on the variability in the blight pathogen, *Ascochyta rabiei*. Other students studied groundnut rust and leaf spot diseases, the adoption of modern cereal cultivars in India, the effects of staggered sowing dates and plant proportions in a legume/cereal intercrop, the effects of sowing dates and irrigation on the yield of two rainy-season sorghum cultivars, and marketed surplus, household inventories, and price expectations in the semi-arid tropics of India.

Seven apprentices from four countries were associated with research scientists in work-study programs.

Continuing its tradition of international training courses in legume pathology, ICRISAT hosted the seventh such course in January. For the first time, the course dealt with all three legumes on the Institute's mandate, pigeonpea, chickpea, and groundnut. The course was designed to enable participants to diagnose diseases associated with the three crops; to identify and characterize the related fungi, viruses, and nematodes; and to learn techniques to screen breeding material for resistance to major pathogens.

Also in January, 10 participants from nine countries in Africa and Asia began a 6-week training course in socioeconomics, the third in the last 4 years. Topics included identifying and alleviating production constraints, economic considerations for interdisciplinary farming systems research, and effective use of microcomputer software in economics research.

The first International Training Workshop on Groundnut Modeling began in late March. Twenty-two scientists attended the 12-day workshop which tested and validated the groundnut model 'PNUTGRO', developed by the University of Florida, USA. Participants in the workshop, which was cosponsored by the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT), are now expected to train national program scientists in their countries. Those from India and Thailand will conduct experiments during 1987/88 so that a uniform minimum data set on climate, soil, and crop can be collected to further improve the model.

Research scholar from Kenya studies how height expression is inherited in pigeonpea.

Research scholar from Kenya studies flowering mechanisms in pigeonpea.

Training of research technicians in progress in a newly built training facility at the SADCC/ICRISAT regional cereals program in Zimbabwe.

A course on techniques in the production and evaluation of pigeonpea hybrids using genetic male sterility was organized at ICRISAT Center in October. Fourteen participants from agricultural universities, the Indian Council of Agricultural Research (ICAR), and private and public sector seed organizations attended the course.

In regional training programs, 16 scientists from seven SADCC countries and Burundi participated in a 6-week training course on research station management at Matopos, Zimbabwe. Seven technicians from four SADCC countries spent 4 weeks at Matopos for training in crop improvement and agronomy of sorghum and millet.

In individualized training at ISC, Niger, 14 students from four countries studied diverse topics: effect of soil fertility on crop establishment in pearl millet and influence of sowing date on the incidence of downy mildew, soil management practices for rainfed agriculture, animal traction, seed and seedling diseases and techniques for diagnosis of groundnut diseases.

During the year, ICRISAT continued to increase its training activities, as part of the overall effort to maximize the transfer of technology in association with partners in national programs.

ICRISAT Senior Staff— as of December 1987

ICRISAT Center

Administration

L D Swindale, Director General
J S Kanwar, Deputy Director General
M Gibon, Assistant Director General (Administration)
K B Srinivasan, Assistant Director General (Liaison)
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 on Research Management Systems (until Apr)
V Balasubramanian, Sr Executive Officer (Director General's Office)
Joyce Gay, Sr Adm Secretary to DG
M S S Reddy, Scientist (on contract, until Aug)
Saradha Sagar, Sr Adm Secretary to the DDG (until Sep)
Surendra Mohan, Sr Adm Officer, Office of the DDG (from Aug)
K Sampath Kumar, Sr Secretary, Office of the DDG
S Krishnan, Asst Manager (Admn) (Office of Adviser to DG for Donor Relations)
S Geetha, Sr Secretary, Office of the ADG (Admn)
P S Susamma Nair, Adm Officer, Office of the ADG (Liaison)
D Mitra, Fiscal Manager
A Banerji, Assistant Manager (Fiscal)
V S Swaminathan, Sr Accounts Officer
A N Venkataswamy, Sr 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
T Kulashekhar, Accounts Officer
T K Srinivasan, Accounts Officer
B K John, Personnel Manager (on leave from Apr)
P M Menon, Personnel Manager (Acting, from Apr)
N S L Kumar, Sr Personnel Officer
P Suryanarayana, Sr Personnel Officer
A Hameed, Personnel Officer (from Jul)
A J Rama Rao, Sr Secretary (Personnel)
R Vaidyanathan, Purchase and Stores Manager
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 (Administration, until Dec)
N Surya Prakash Rao, Sr Resident Medical Officer
G Vijayakumar, Transport Officer (until Apr)
K Jagannadham, Adm Officer (Transport)
A Rama Murthy, Travel Officer
V V Ramana Rao, Adm Officer

Research Programs

Cereals

Program Office

J M J de Wet, Program Director,
K Santhanam, Asst Manager (Adm)
Nirmala Kumar, Adm Officer (until Apr)

Sorghum Group

S Z Mukuru, Principal Plant Breeder
L K Mughogho, Principal Plant Pathologist (on sabbatic)
J M Peacock, Principal Plant Physiologist (on sabbatic from May)
K F Nwanze, Principal Cereals Entomologist
D S Murty, Plant Breeder (on leave)
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 (on leave)
R Bandyopadhyay, Plant Pathologist
S L Taneja, Entomologist
H C Sharma, Entomologist (on sabbatic until Oct)
H D Patil, Sr Research Associate (on leave from Jun)
K David Nicodemus, Sr Research Associate
D J Flower, International Intern
H Kokubu, Postdoctoral Fellow (from July)

Pearl Millet Group

S B King, Principal Plant Pathologist
F R Bidinger, Principal Plant Physiologist
J R Witcombe, Principal Plant Breeder
K K Lee, Principal Cereals Microbiologist
C T Hash, Associate Principal Plant Breeder (from Apr)
K N Rai, Plant Breeder (on sabbatic from Apr)

B S Talukdar, Plant Breeder
Pheru Singh, Plant Breeder (on leave from Aug)
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 until Jun)
S P Wani, Microbiologist
K R Krishna, Microbiologist
M N Pawar, Sr Research Associate (until Apr)
B P Reddy, Sr Research Associate
P Q Craufurd, International Intern (until Feb)
C T Hash Jr, International Intern (until Mar)
E Weltzien, Postdoctoral Fellow (from Nov)

Kenya

V Y Guiragossian, SAFGRAD-ICRISAT Coordinator for Sorghum and Millet, Eastern Africa

Mexico

C L Paul, Team Leader and Principal Sorghum Agronomist
R Clara, Scientist, Sorghum Breeder

Legumes

Program Office

Y L Nene, Program Director,
D G Faris, Principal Coordinator, Asian Grain Legumes Network (on sabbatic from Aug)
C L L Gowda, Acting Coordinator, AGLN (from Aug)
D M Pawar, Sr Agricultural Officer (Cooperative Trials LEGOFTEN)
Surendra Mohan, Sr Adm Officer (until Apr)
P Rama Murthy, Adm Officer
G J Michael, Adm Officer

Pulses Group

W Reed, Principal Entomologist (until Nov)
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/ODNRI
J Arihara, Associate Principal Physiologist
N Ae, Associate Principal Microbiologist
H J Hansen, Asst Principal Plant Pathologist, ICRISAT/DANIDA
K Okada, Asst Principal Microbiologist
D Sharma, Sr Plant Breeder, Pigeonpea (until Jul)
K C Jain, Plant Breeder, LEGOFTEN
Onkar Singh, Plant Breeder, Chickpea (on sabbatic from Jul)
K B Saxena, Plant Breeder, Pigeonpea
S S Lateef, Entomologist
M P Haware, Plant Pathologist (on leave)
S C Sethi, Plant Breeder, Chickpea
N P Saxena, Agronomist (Physiology)
O P Rupela, Agronomist (Microbiology)
J V D K Kumar Rao, Agronomist (Microbiology) LEGOFTEN
A M Ghanekar, Plant Pathologist
Jagdish Kumar, Plant Breeder, Chickpea
S Sithanantham, Entomologist (on leave from Jul)
S C Gupta, Plant Breeder, Pigeonpea
M V Reddy, Plant Pathologist
Y S Chauhan, Agronomist (Physiology)
S B Sharma, Plant Nematologist
M D Gupta, Sr Research Associate
N V Ratnam, Sr Research Associate
J H Miranda, Sr Research Associate, Chickpea
Sheila Vijay Kumar, Sr Research Associate
L Krishna Murthy, Sr Research Associate
P K Anand Rao, Postdoctoral Fellow (until Jan)
Nandita Sarkar, Postdoctoral Fellow
S K Singh, Postdoctoral Fellow (from May)
F B Lopez, Postdoctoral Fellow (from Jun)
A Schroth, Research Scholar (from Oct)

Groundnut Group

D McDonald, Principal Plant Pathologist
J P Moss, Principal Cytogeneticist
D V R Reddy, Principal Plant Virologist
J H Williams, Principal Plant Physiologist (on sabbatic from May)
J A Wightman, Principal Entomologist
S N Nigam, Principal Plant Breeder
F Waliyar, Asst Principal Plant Pathologist
L J Reddy, Plant Breeder
P Subrahmanyam, Plant Pathologist (on leave)
P T C Nambiar, Microbiologist (on sabbatic from Apr)
P W Amin, Coordinator and Entomologist, LEGOFTEN
G V Ranga Rao, Entomologist
A K Singh, Cytogeneticist (on sabbatic until Jun)
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
N Sivananda Reddy, Sr Research Associate
Y Sudhakar Yekula, Postdoctoral Fellow (from Jun)
C S Gold, Postdoctoral Fellow (from Sep)
R A Naidu, Postdoctoral Fellow (from Jan)

Syria

K.B.Singh, Principal Chickpea Breeder
M.P.Haware, Principal Chickpea Pathologist

Pakistan

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

Resource Management

Program Office

J.L.Monteith, Program Director
S.K.Sharma, Sr Research Associate
R.S.Aiyer, Sr Adm Officer
S.Ramachandran, Adm Officer

Agronomy Group

S.M.Virmani, Principal Agroclimatologist
J.R.Burford, Principal Soil Chemist (on sabbatic until May)
C.K.Ong, Principal Agronomist, Cropping Systems
R.J.Van Den Beldt, Principal Agronomist, Agroforestry (until Mar)
R. Tabo, Principal Agronomist (from Aug)
A.Schütt, Asst Principal 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.S.Reddy, Agronomist (until Aug)
M.Natarajan, Agronomist (until Jul)
A.Ramakrishna, Agronomist
C.S.Pawar, Entomologist
A.A.H.Khan, Engineer
R.Tabo, Postdoctoral Fellow (until Jul)
J.N.Daniel, Postdoctoral Fellow (from Sep)

Engineering Group

K.B.Laryea, Principal Soil Physicist
T.Takenaga, Principal Agricultural Engineer
G.D.Smith, Principal Soil Scientist, ICRISAT/QDPI (from Feb)
Sardar Singh, Soil Scientist
K.L.Srivastava, Agricultural Engineer
R.K.Bansal, Agricultural Engineer (on leave)
R.C.Sachan, Agricultural Engineer
Prabhakar Pathak, Agricultural Engineer
N.K.Awadhwal, Agricultural Engineer/Soil Physicist
V.M.Mayande, Engineer
M. Bonsu, Postdoctoral Fellow (from Aug)

Economics Group

T.S.Walker, Principal Economist
P.J.Matlon, Principal Economist (on sabbatic)
R.A.E.Müller, Principal Economist
Karen Ann Dvorak, Principal Economist, ICRISAT/IFDC (until Sep)
N.S.Jodha, Sr Economist (on leave from Apr)
R.N.Athavale, Sr Hydrologist (until Jun)
R.D.Ghodake, Economist (until Apr)
R.P.Singh, Economist (on sabbatic from Apr)
M.Asokan, Sr Research Associate (on study leave from Dec)
K.G.Kshirsagar, Sr Research Associate (on study leave from Apr)
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

Support Programs

Biochemistry

R.Jambunathan, Principal Biochemist and Program Leader
Umaid Singh, Biochemist
V.Subramanian, Biochemist
S.Sivaramakrishnan, Biochemist
P.Subrahmanyam, Sr Adm Officer
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
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, Administrative Officer
Y.Saigeshwara Rao, Postdoctoral Fellow (from Jun)

Plant Quarantine

B K Varma, Chief Plant Quarantine Officer (until Nov)
N C Joshi, Chief Plant Quarantine Officer
(on contract, from Dec)
Upendra Ravi, Sr Research Associate
N Rajamani, Sr Adm Officer

Fellowships and Training

D L Oswalt, Principal Training Officer
and Program Leader
B Diwakar, Sr Training Officer
T Nagur, Sr Training Officer
S K Dasgupta, Sr Training Officer (on sabbatic until May)
Faujdar Singh, Training Officer
V S Raju, Sr Secretary (until Oct)

Information Services

D A Fuccillo, Head
J B Wills, Research Editor
Susan D Hall, Research Editor
S M Sinha, Asst Manager, Art and Production
D R Mohan Raj, Editor
J J Abraham, Editor
Madhu Reddy, Editor (until Jan)
V Sadhana, Editor (from Apr)
H S Duggal, Sr Photographic Supervisor (until Sep)
G K Guglani, Sr Art Visualizer
T R Kapoor, Sr Composing Supervisor
A Antonisamy, Printshop Supervisor
A B Chitnis, Sr Photographer
N V N Chari, Adm Officer

Statistics

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, Senior Computer Programmer/Analyst
C Kameswara Rao, Computer Programmer/Analyst
(until Apr)
S V Nanda Kishore, Computer Programmer/Analyst
J Gnanasekharan, Computer Programmer/Analyst
(until Oct)
E A Vinod Kumar, Computer Programmer/Analyst
(from Nov)
G Subba Raju, Computer Programmer/Analyst (from Nov)

Library and Documentation Services

L J Haravu, Manager
P K Sinha, Sr Documentation Officer
P S Jadhav, Sr Library Officer
S Prasannalakshmi, Sr Library Officer
R G Naidu, Documentation Officer
V Venkatesan, Library Officer (on leave from Aug)

Housing and Food Services

D A Evans, Manager (from Feb)
S Mazumdar, Asst Manager (Food Services)
B R Revathi Rao, Asst Manager (Housing)
D V Subba Rao, Asst Manager (Warehouse)
D N Sar, Canteen Officer

Physical Plant Services

V P McGough, Manager
W B Symons, Principal Engineer (from Aug)
Sudhir Rakhra, Chief Engineer (Civil)
D Subramaniam, Chief Engineer (Electrical)
C K Belliappa, Asst Manager (Workshop) (until Jan)
S K V K Chari, Sr Engineer
(Electronics and Instrumentation) (until Jan)
N S S Prasad, Sr Engineer (Electronics and
Instrumentation)
A R Das Gupta, Sr Engineer (Communication)
D C Raizada, Sr Engineer (Airconditioning)
K Ravi Kumar, Sr Engineer (from Apr Oct)
R Thiyagarajan, Engineer (Automobiles) (until Mar)
A N Singh, Engineer (Heavy Equipment and Tractors
S W Quader, Engineer (Office Equipment)
K R C Bose, Engineer (Civil)
K Satyanarayana Raju, Engineer (from May)
V Madhusudan Rao, Engineer
Y Chiranjeevi Rao, Engineer
S P Jaya Kumar, Sr Adm Officer

Farm Development and Operations

D S Bisht, Manager (from Jul)
S N Kapoor (Acting Manager until Jul), Manager (Far
Machinery)
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
S C Gupta, Engineer

T.A.Krishnamurthi, Sr Adm Officer (until Apr)
Surendra Mohan, Sr Adm Officer (from Apr to Aug)
V.S.Raju, Adm Officer (from Oct)

West African Programs

ICRISAT Sahelian Center, Niger

Administration

R.W.Gibbons, Executive Director, West African Programs, and Director, ICRISAT Sahelian Center
D.C.Goodman Jr, Regional Adm Officer (until Mar)
M.G.Wedeman, Regional Adm Officer (on special assignment from Apr)
M.Adjei-Fah, Adm Secretary
M.D.Diallo, Regional Fiscal officer (from Oct)
I.Agani, Accountant
K.A.Moussa, Personnel and Transport Officer
Solange Delanne, Executive Asst (Liaison)
B.Amadou, Adm Asst (Travel) (from Nov)
A.R.Tanko, Purchase officer
I.Laouali, Computer Programmer/Analyst
I.J.Cachalo, Bilingual Secretary

Research Programs

Pearl Millet Improvement Program

K.Anand Kumar, Principal Millet Breeder and Team Leader
S.O.Okiror, Principal Millet Breeder/Regional Trials Officer
S.N.Lohani, Principal Millet Breeder (Burkina Faso)
M.Mahamane, Bilingual Secretary (from Jul)
L.Marchais, Principal Geneticist (ORSTOM)
S.Tostain, Principal Geneticist (ORSTOM)
M.J.Lukefahr, Principal Millet Entomologist
A.Mamalo, Research Technician
J.Werder, Principal Millet Pathologist
A.A.Cissé, Research Asst (from Jul)
L.K.Fussell, Principal Millet Agronomist (on sabbatic until Sep)
T.J.Stomph, Sr Research Asst

Groundnut Improvement Program

B.J.Ndunguru, Principal Groundnut Agronomist and Team Leader
D.C.Greenberg, Principal Groundnut Breeder
P.Subrahmanyam, Principal Groundnut Pathologist

Resource Management Program

C.Renard, Principal Agronomist and Team Leader,
M.Manzo, Research Asst
M.V.K.Sivakumar, Principal Agroclimatologist (on sabbatic from Oct)
S.Abdoussalem, Research Asst
A.Bationo, Principal Soil Chemist (IFDC)
M.C.Klaij, Principal Soil and Water Management Scientist
P.Ouedraogo, Sr Research Asst
A.Tekete, Principal Agronomist (University of Hohenheim) (until Dec)
J.Kaziende, Research Asst
B.R.N'tare, Principal Cowpea Breeder/Agronomist (IITA)
M.S.Dicko, Principal Animal Nutritionist (ILCA) (on sabbatic until May)
S.Coulibaly, Research Technician
J.C.Hopkins, Postdoctoral Fellow (IFPRI) (from Jul)
R.J.Van Den Beldt, Principal Agronomist/Agroforestry (from May)
M.Djibey, Research Asst (from May)
J.Toll, IBPGR Field Officer for West Africa (from Feb)
V.Watt, IBPGR Collector for the Sahel (from Jun)
A.N'Diaye, Bilingual Secretary (from Mar)

Support Programs

Farm Operations

P.G.Serafini, Research Farm Manager
R.van Midde, Technical Asst (SNV)
P.Koudogbo, Chief Mechanic
B.Mallam, Security Officer

Construction

B.D.Marvaldi, Project Development Officer

Statistics

B.Gilliver, Principal Statistician
G.Ouoba, Computer Programmer

Information/Documentation

C.Giroux, Regional Information Officer
A.Dodo, Translator
F.Gbaguidi, Librarian
H.Diori, Documentalist (from Mar)

Burkina Faso

Administration

C.M.Pattanayak, Principal Sorghum Breeder and SAFGRAD/ICRISAT Coordinator
A.Tenkouano, Research Associate
A.Coulibaly, Bilingual Adm Secretary
B.T.Ouedraogo, Adm Asst (General Service)
S.Lingani, Adm Asst (Accounts)
L.Yoni, Computer Technician

Research

K.V.Ramaiah, Principal Cereal Breeder—*Striga*
D.S.Murty, Principal Sorghum Breeder
M.D.Thomas, Principal Sorghum Pathologist
G.Hoffman, Principal *Striga* Agronomist (from Aug)
N.Kaboré, Technician
T.Traoré, Technician
S.Sawadogo, Technician

Mali

S.V.R.Shetty, Principal Agronomist and Team Leader
N.F.Beninati, Principal Breeder
I.Kassambara, Research Associate (Sotuba)
A.Coulibaly, Research Associate (Cinzana)
S.Touré, Adm Asst
B.Sogoba, Accounts Asst

Southern Africa Programs

SADCC Regional Sorghum and Millet Improvement Program, Zimbabwe

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

Regional Groundnut Improvement Program, Malawi

K.R.Bock, Principal Groundnut Pathologist and Team Leader
G.L.Hildebrand, Principal Groundnut Breeder (from Aug)

ICRISAT Governing Board—1987

Dr F. V. MacHardy, Chairman
7817 Saskatchewan Drive
Edmonton, Alberta
Canada T6G 2L3.

Dr N. S. Randhawa, Vice Chairman
Director General, Indian Council of
Agricultural Research (ICAR) and
Secretary to the Government of India
Department of Agricultural Research
and Education
Krishi Bhavan
New Delhi 110 001
India

Dr L. D. Swindale. Ex-Officio Member
Director General, ICRISAT
Patancheru
Andhra Pradesh 502 324
India

Mr C. S. Sastry
Secretary to the Government of India
Ministry of Agriculture
Krishi Bhavan
New Delhi 110 001
India

Mr Snravan Kumar
Chief Secretary to the
Government of Andhra Pradesh
Secretariat
Hyderabad 500 022
India

Dr P. L. Adkisson
Chancellor
Texas A & M University System
College Station
Texas 77843
USA

Dr L. Brader
Director
Plant Production and Protection Division
Food and Agriculture Organization of the UN
Via delle Terme di Caracalla
00100 Rome
Italy

Dr C. Charreau
Director, IRAT
Centre de Coopération Internationale en Recherche
Agronomique pour le Développement (CIRAD)
45 bis Avenue de la Belle Gabrielle
94130 Nogent-sur-Marne
France

Dr J. P. Eckebil
Director
Institut de la Recherche Agronomique
B.P. 2123
Yaounde - Messa
Cameroon

Dr N. L. Innes
Deputy Director
Scottish Crop Research Institute
Invergowrie, Dundee
Scotland

Dr K. Kumazawa
Professor of Plant Nutrition and Fertilizer
Faculty of Agriculture
University of Tokyo
Bunkyo-ku, Tokyo
Japan

Dr W. T. Mashler
4 Woody Lane
Larchmont, New York 10538
USA

Dr J. Moncada de la Fuente
Presidente
Colegio de Ingenieros Agronomos
de Mexico, A.C.
Sindicalismo 92
Mexico 18, D.F.

Dr B. K. Patel
Chief Agricultural Research Officer
Department of Agriculture
Mount Makulu Research Station
PO Box 7
Chilanga
Republic of Zambia

Dr P. M. A. Tigerstedt
Department of Plant Breeding
University of Helsinki
00710 Helsinki
Finland