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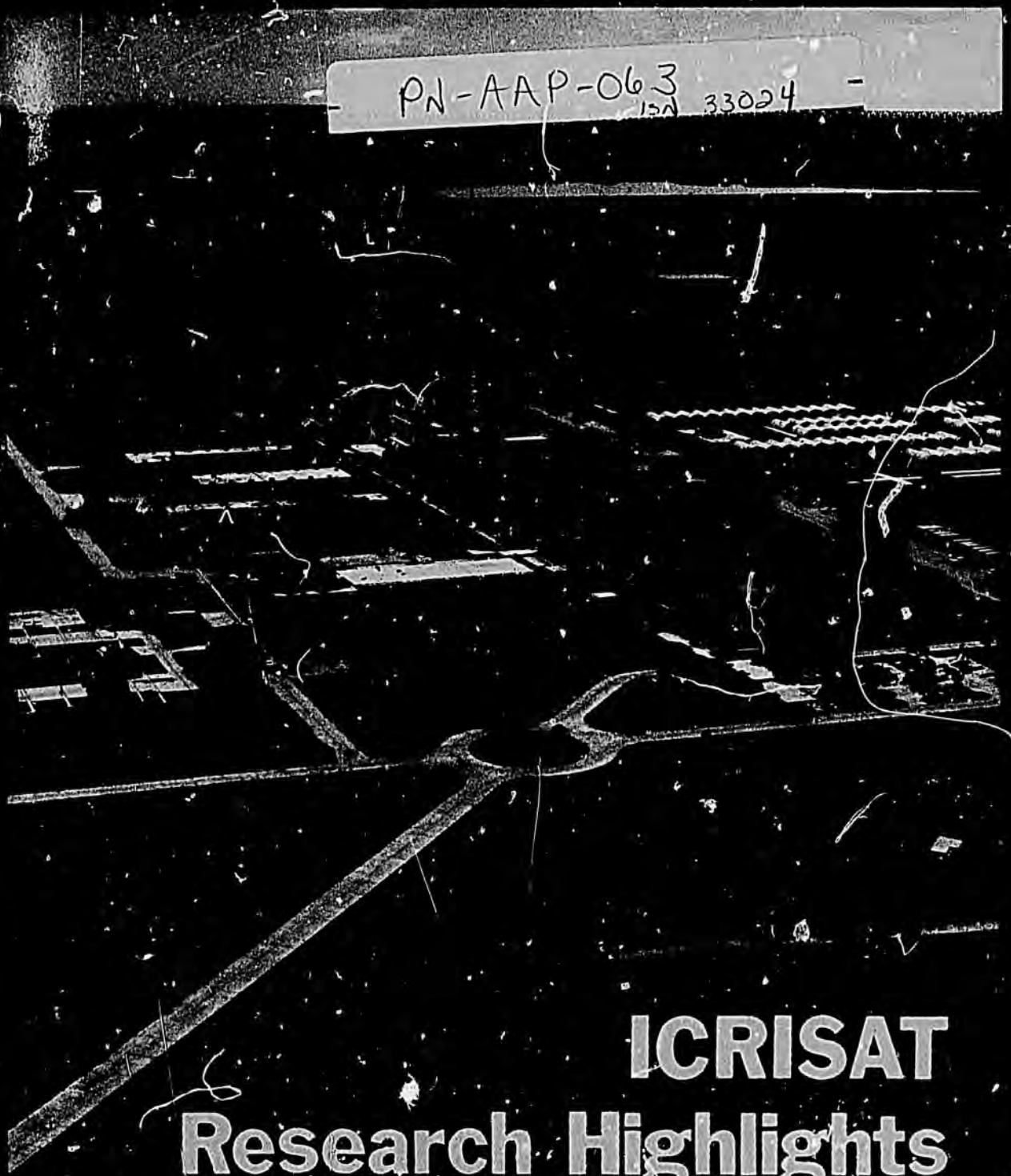

ICRISAT Research Highlights 1982

International Crops Research Institute for the Semi-Arid Tropics

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Cover: An aerial view of ICRISAT Center, Patancheru, India, at the 10th Anniversary Observance, October 1982.

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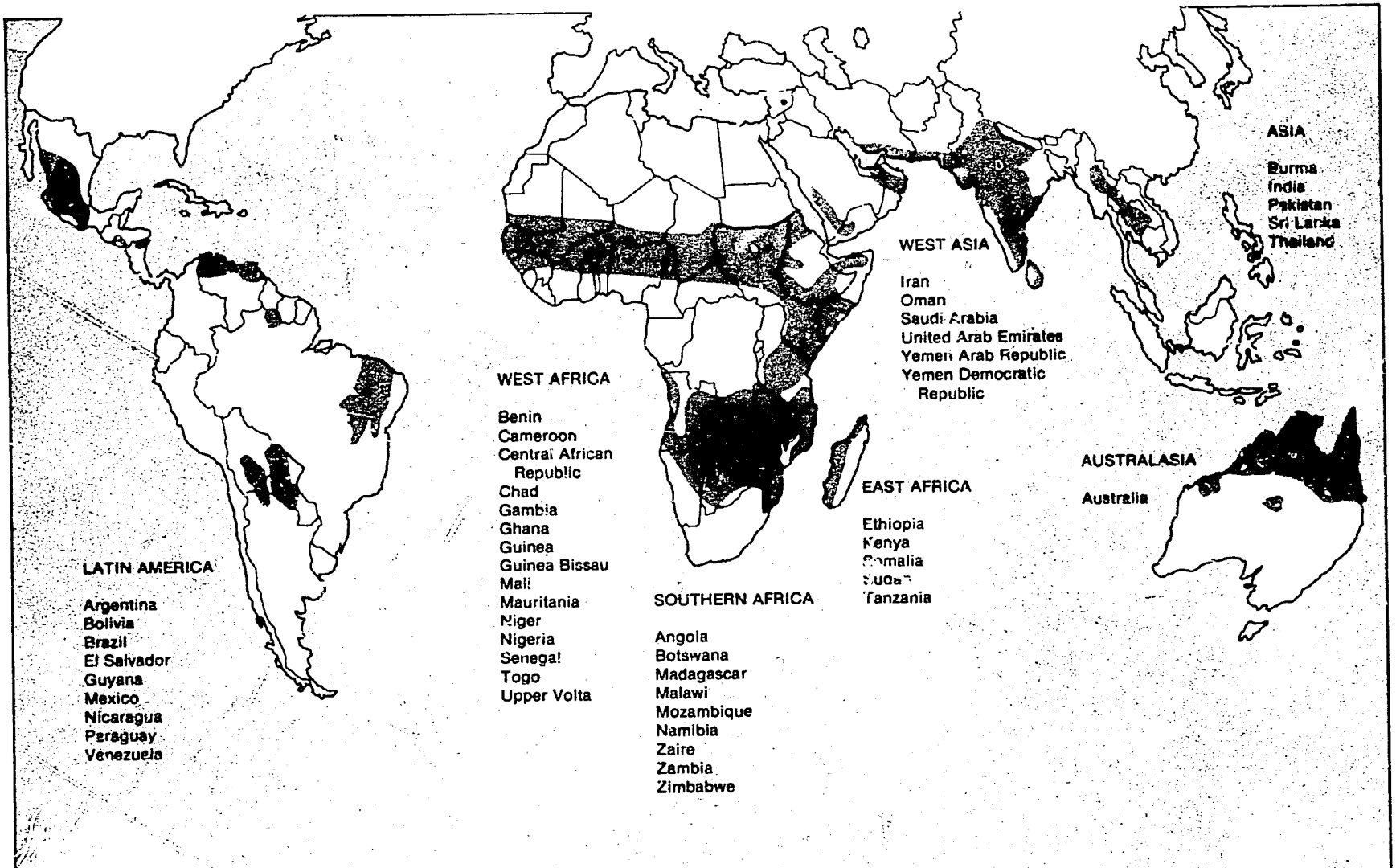


Semi-arid areas (in yellow) covered by ICRISAT's mandate. Green squares indicate location of ICRISAT Center in India and Sahelian Center in Niger; red dots indicate collaborative research stations with resident ICRISAT staff.

About ICRISAT

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

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

The SAT is a harsh region of limited, erratic rainfall and nutrient-poor soils; it is populated by more than 700 million people, most of them living at subsistence levels and dependent for their food upon 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 pigeonpea, chickpea, 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 eight countries of Africa, in Mexico, in Syria, and at six cooperative research stations of agricultural universities in India. Principal operations in Africa are in Niger, Upper Volta, Mali, Senegal, Nigeria, Sudan, Kenya, and Malawi. The main base for ICRISAT's future work in Africa will be at the new Sahelian Center now being developed near Niamey, Niger. Other scientists are posted at experiment stations of the countries concerned.

Introduction

For ICRISAT, 1982 was a signal year—the end of a decade of work in India, the beginning of research at the ICRISAT Sahelian Center in West Africa.

At our 10th Anniversary observance at ICRISAT Center on 11 October, we were able to review accomplishments with satisfaction and view the challenges ahead with confidence. Many of the research results and much of the germplasm we amassed during our first decade can be transferred with assurance to scientists and farmers in SAT countries.

In Africa, we began operations at the new ICRISAT Sahelian Center in Niger. The 500-hectare experiment farm near Niamey will be the focal point for our work on millets and groundnuts, and on farming systems associated with those crops in the southern Sahelian zone of West Africa. It will also serve as the headquarters for our West Africa programs.

In response to requests of the nine Heads of State of the Southern African Development Coordination Conference, we began a regional groundnut improvement program in Malawi, to benefit southern and eastern Africa, and are now planning similar cooperative regional programs in sorghum, pearl millet, and dryland farming systems.

Important advances were made in 1982 in all of our crop improvement programs.

ICRISAT-related sorghums were in production in Mexico and Central America, and in several African countries, were released to farmers in China after 2 years of testing, and neared release in India, which tests cultivars for up to 6 years before releasing them to farmers.

Our first pearl millet released in India, high yielding and resistant to downy mildew, went into commercial seed production, and another variety entered its final year of testing. In Senegal, two ICRISAT millet synthetics bred in that country advanced to on-farm evaluation after outyielding the improved local variety by an average 22% over 3 years.

A chickpea developed by ICRISAT and our sister institute ICARDA to resist ascochyta blight was released in 1982 for winter sowing and general cultivation in drier zones of Syria, and another variety was multiplied for large-scale trials in Jordan.

We developed with the University of Queensland a system of using high-yielding, early-maturing pigeonpeas for improved production in Australia. A similar improved production system, accepted in Fiji, is expected to make that country self-sufficient in pigeonpea, and indicates the potential use of such systems in other developing countries.

Our groundnut program distributed 4187 populations and breeding lines to 31 countries and made further advances against diseases, particularly rust and late leaf spot. We also made significant progress in breeding for resistance to diseases and pests in other crops.

In India our efforts to transfer technology for double cropping deep black soils expanded dramatically. We were encouraged by the results of our first year of on-farm experiments with this technology in Taddanpally village near ICRISAT Center and initiated similar projects in seven other villages in four states of India in cooperation with their departments of agriculture and participating farmers. We also trained at ICRISAT Center some 100 Indian agricultural specialists who will implement projects being established in various locations in those four states.

These and other research advances in 1982 are reported in more detail on the pages that follow and in the 1982 ICRISAT Annual Report.

L.D. Swindale
Director General

Planting chickpea between rows of pigeonpea after a sorghum harvest at Begumganj, Madhya Pradesh. ICRISAT's on-farm testing of technology spread to eight locations in India in 1982.

Meeting the Sahelian Challenge

ICRISAT opened a new frontier in 1982 for its agricultural research in West Africa--and in about the harshest cropping environment imaginable.

The ICRISAT Sahelian Center covers 500 hectares of hot, sandy soil selected by ICRISAT and provided by the Government of Niger for a research center at Sadoré, near the capital city of Niamey. It is in a drought-prone area where 70% of the annual rainfall occurs within 5 weeks, soil temperatures can reach 60°C (140°F), and the soil is 92% sand.

The Center will be ICRISAT's main base in Africa for research in millets and groundnuts, and on farming systems associated with those crops in the food-deprived southern Sahelian zone. It will be the Institute's only owned facility in Africa. Our scientists posted in other countries work at national research centers of those countries.

We started with a staff of five scientists, fenced the area, erected temporary buildings, and planted several experiments in the 56 hectares designated initially for crop research. The ICRISAT interdisciplinary team will be augmented in 1983 by an animal nutritionist from the International Livestock Center for Africa (ILCA). ICRISAT groundnut scientists will join later. Construction of permanent laboratory and office facilities will begin in 1984.

There are inherent difficulties in establishing a new research station, as illustrated in these excerpts from the team's 1982 Annual Report:

"Important factors that prevent high yields in the Sahel are uneven plant stands due largely to sand storms and high temperatures when plants emerge, downy mildew, and *Raghuva* and *Acigona* (two insect pests). . .

"The first major shower (32.8 mm, 26 May) was followed by 24 days of dry weather. Planting was begun 21 June after a 39.9-mm shower; rainfall then was adequate, though erratic, until 28 July. Only 76.7 mm fell after that, so late-season development was unsa-

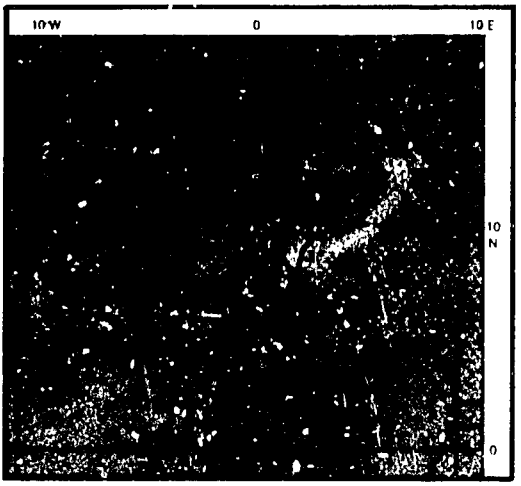
Millet plants hit by blowing sand in the harsh cropping environment at ICRISAT's Sahelian Center.

tisfactory. Total rainfall for the season was only 395.9 mm, compared with a mean for Niamey of 580 mm. Consequently, growth of experimental material was poor and few useful conclusions could be drawn. . .

"Very few test plants in the disease nurseries at Sadoré survived beyond the seedling stage, and almost none produced heads. Low soil fertility was aggravated by late planting, leaching of nutrients, and pests. By contrast, growth in the 0.75-ha disease garden (sown 6 July) was satisfactory. It was newly cleared of bush so its fertility was higher than that of the main experimental field, which had been cropped previously."

Despite those initial difficulties, we are fully confident that our scientists will establish in 1983 a comprehensive series of experiments that will open the way to our bringing the benefits of modern agricultural research and technology to the deprived farmers in that area.

The ICRISAT team working on millets in Niger will complement one working on sorghums in Upper Volta, previously our largest interdisciplinary team in Africa. Those two cereals are food staples in the Sahelian zone* a subsistence requirement for millions of undernourished people. Other



ICRISAT Sahelian Center (located at Sadoré, near Niamey) will focus its work on the southern Sahelian zone in Africa.

ICRISAT scientists are working in cereals or groundnuts in regional or national programs based in Senegal, Mali, Sudan, Nigeria, Kenya, and Malawi.

In both Niger and Upper Volta, ICRISAT economists are conducting village-level studies in close cooperation with crop improvement and farming systems scientists. A social anthropologist also works in Upper Volta.

The bare plot at left was transformed into the millet field at right as crop research began at the Sahelian Center.

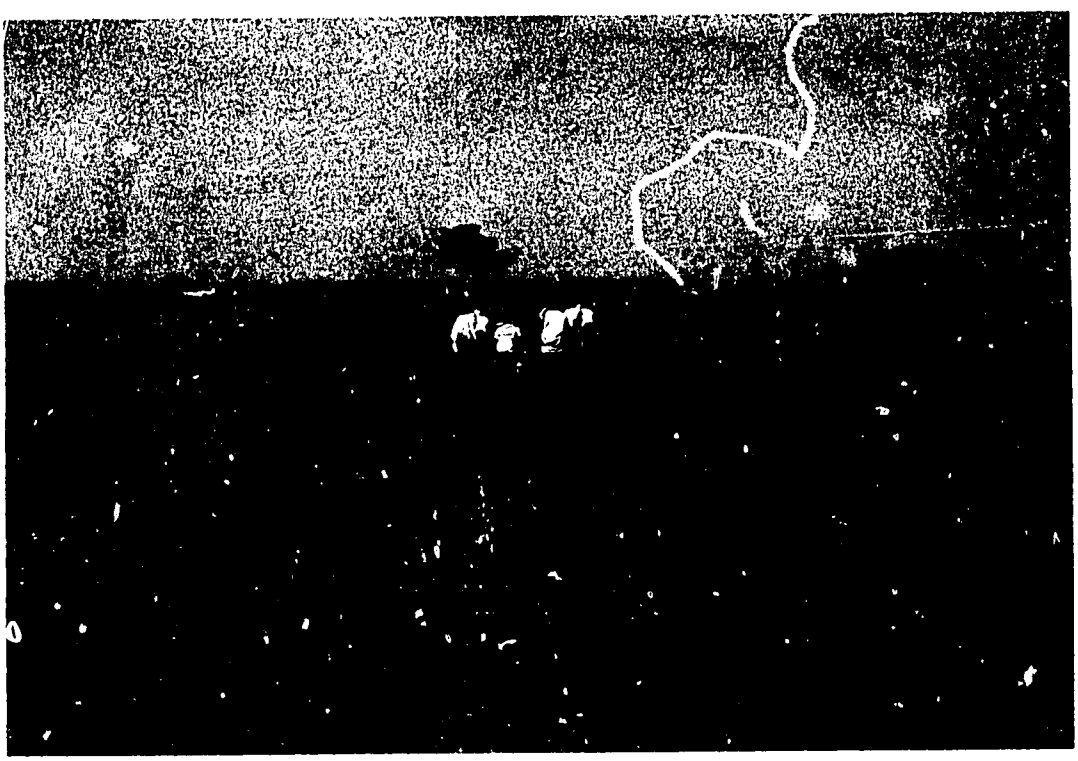
Double Cropping Deep Black Soils

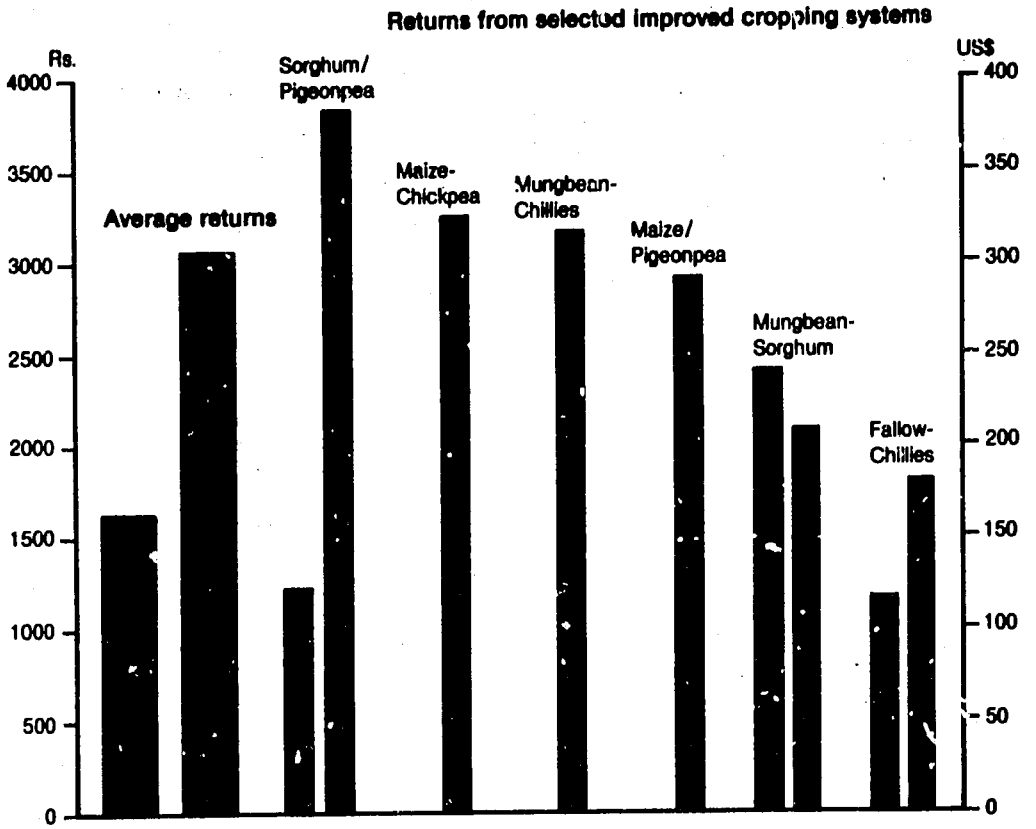
We expanded in 1982 our on-farm testing of technology to grow two crops a year on deep black soils now producing only one in many parts of India. In addition to the pilot project started last year in Taddanpally village, 42 km from ICRISAT Center, we worked closely with agricultural officials and farmers to establish similar experiments in seven other villages in four states of India. We also helped train extension officers to take the technology into other areas.

Results from the first year's experience at Taddanpally were encouraging. The nine crop combinations that the 14 participating farmers chose for cultivation in the rainy and postrainy seasons far exceeded production of neighboring farms that grew only a postrainy-season crop. Their returns averaged Rs. 3059 per hectare, compared with Rs. 1625 for the traditional farmers. The improved systems required an extra investment of Rs. 588 per hectare, but produced extra income of Rs. 1434 per hectare—a return of 244% on the added expense.

Problems were encountered, as expected. The witchweed *Striga* and the pod borer

Cultivating broadbeds and furrows at Taddanpally with the bullock-drawn wheeled tool carrier.





Farmers' income from traditional (red) and improved (green) cropping systems at Taddanpally village, 1981/82.

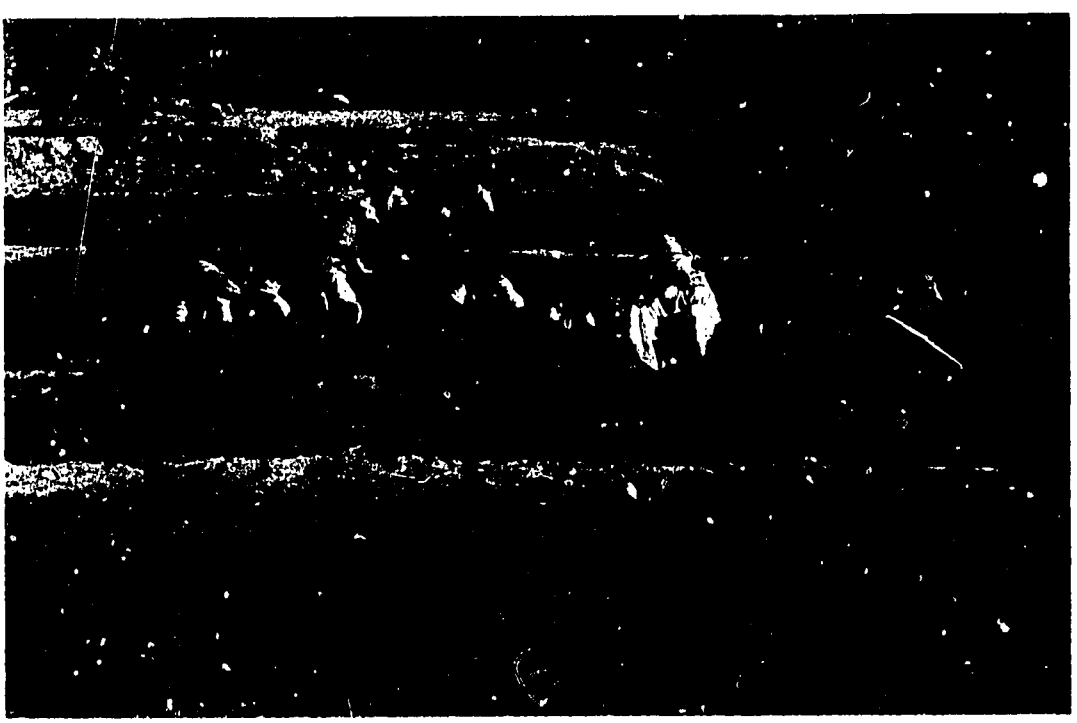
Heliothis armigera substantially reduced yields of sorghum and pigeonpea, respectively, in the rainy-season crops. Threshing and storage were problems, particularly because the year was so wet (total rainfall 871 mm, with 241 mm in September) that sorghum heads did not dry in the field.

Nevertheless, 6 of the 14 farmers decided to continue using the double cropping technology in 1982/83, and 17 farmers in the neighboring village of Sultanpur asked for a similar test on their watershed of 35.2 hectares, which ICRISAT and the Government of Andhra Pradesh are providing this year. We are also working closely with local officials and farmers on similar experiments at six locations in Madhya Pradesh, Maharashtra, and Karnataka.

The eight locations at which ICRISAT's on-farm technology was tested in 1982 are in widely separated areas with different agroclimatic characteristics, but all are in assured rainfall zones—a must for the double cropping technology.

It is estimated that from 5 to 12 million hectares of deep black soils that could be cultivated twice a year in India are now being left fallow during the rainy season when the soil becomes sticky, and crops such as sorghum, chickpea, and wheat are grown

Pigeonpea harvesting at Taddanpally: ICRISAT's on-farm results showed that two crops a year could be grown on land presently growing only one. Chillies (below) were among the nine crop combinations farmers grew in Taddanpally.



only after the rains, on the residual soil moisture.

ICRISAT's technology, developed and refined in close collaboration with Indian research institutions, involves:

- shaping the land into graded broadbeds and furrows to facilitate cultivation and surface drainage;
- preparing seedbeds during the dry season with improved bullock-drawn equipment;
- sowing dry just ahead of the monsoon;
- using moderate amounts of fertilizer and recommended high-yielding cultivars;
- cultivating a second crop on the same land after the first crop has been harvested.

The potential for increased food production on these soils is great if the constraints to farmers taking up the new technology are removed. The following issues, some of which arose at Taddanpally, are now being discussed with policymakers and must be addressed as a prerequisite to any rapid transfer of the technology.

- Bullock power could be a problem for small farmers, who may require loans for custom hiring or purchase.
- Special government programs may be necessary to construct community drainage if farmers on a watershed won't or can't afford to do it themselves.
- Markets may be needed for new crops in the improved system.
- Credit schemes and additional bank offices are needed to enable farmers to purchase or hire wheeled tool carriers.
- Farmers should not be required to repay rainy-season loans before receiving loans for their postrainy-season crops; this would avoid critical delays in operations.
- More fertilizer, plant protection, and chemical distribution centers are needed in these areas of assured rainfall.
- National research and extension staff must be trained in the basic components of the technology so they can modify or adapt it to local situations.

Nevertheless, our experience with our collaborators—including farmers—suggests that in practice many of these constraints can be overcome through close cooperation between the agencies and individuals concerned.

Sorghum Advances

ICRISAT sorghums are being multiplied around the world. Ten years after the start of research in India, we now see high-yielding, disease- and pest-resistant cultivars in farmers' fields in Africa, Latin America, and China, and nearing release in South Asia. The year just ended was a particularly good one for advancement of this important staple cereal in the semi-arid tropics.

Our efforts in Latin America resulted in release of three sorghum varieties by Mexico's national agricultural institute, release of two varieties in El Salvador, a 50-hectare planting for seed production in Venezuela, an ICRISAT variety going into production channels in Nicaragua, several ICRISAT food-type sorghums being increased in large plots in Guatemala, and eight ICRISAT varieties being increased on farmers' fields in Haiti.

Our sorghum breeder and agronomist posted at CIMMYT in Mexico work closely with that sister institute and with the USAID Title XII Collaborative Research Support Program on Sorghum and Pearl Millet (INTSORMIL). Funded by the International

A Mexican farmer enjoys a sorghum tortilla *in his field. ICRISAT sorghums have been released in Africa, Latin America, and China.*

ICRISAT's elite sorghum variety SPV 351 performed well in advanced testing in India, and moved within a step of release to farmers.

Development Research Centre of Canada (IDRC), they concentrate mostly on developing high-altitude, cold-tolerant sorghums that may have application in other areas such as Kenya and Nepal, and on varieties that can replace maize or be used in combination with it in making tortillas in drier areas where sorghum grows better.

An organization of 10 Latin American countries, the Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos Alimenticios (PCCMCA), gave ICRISAT special recognition in 1982 for the release of sorghum germplasm in Central America, Mexico, and the Caribbean.

In northwestern China, four varieties derived from our population breeding program were released to farmers after 2 years of local selection and evaluation.

In Upper Volta, E 35-1, a high-yielding variety ICRISAT introduced from Ethiopia, continued to gain popularity with farmers. This variety is being used in place of local cultivars for its yield and excellent grain quality, but it thrives only under good management and proper soil conditions.

We posted a sorghum and millet coordinator for southern and eastern Africa in Kenya in 1982. We also have posted sorghum breeders in Sudan and Nigeria.

In India, our elite sorghum variety SPV 351 performed consistently well in advanced testing and moved to within one step of release to farmers. ICRISAT variety SPV 386, which was released to farmers in Zambia this year, was recommended for minikit trials on farmers' fields throughout India in 1983 and our hybrid SPH 221, the top yielder in the 1982 All India Advanced Hybrid Trials, will enter minikit trials in 1984.

Pearl Millet Advances

The first ICRISAT-developed superior pearl millet variety to reach farmers' fields in India, WC-C75, went into commercial seed production this year. We distributed 340 kg to agencies that multiply seed and 970 kg to agricultural departments in various states of India.

Derived from parents of African origin, this new variety with good resistance to downy mildew has undergone rigorous testing in the millet-growing areas of India since 1975.

On average, WC-C75 yields 900 kg/ha in low fertility and 1900 kg/ha in medium fertility conditions. Although these yields are close to those of BJ 104, the most popular Indian pearl millet hybrid, WC-C75 gives 20% more fodder, has better resistance to downy mildew, and suffers less ergot and smut infection.

Farmers can also produce their own seed with it, whereas with a hybrid they must obtain new seed each year.

We also supplied 750 kg of seed of our synthetic variety ICMS 7703 to the All India Coordinated Millet Improvement Project, where it is in the 5th and final year of prerelease trials. An additional 400 kg was distributed to state departments of agriculture.

A medium tall, drought-resistant variety, ICMS 7703 has in 5 years of testing given yields equal to BJ 104, shown low susceptibility to downy mildew (3.3%, compared with

ICRISAT-developed pearl millet variety WC-C75 went into commercial seed production in India. At left is a farmer holding seed bags, at right the variety grown in a field.

Below (left) is one of two ICRISAT millet synthetics that outyielded the popular local variety Souna III in Senegal, and moved to prerelease on-farm evaluation.

11.4% for BJ 104), and given 20% more fodder. It also is less prone to ergot infection.

Two of our millet synthetics bred in Senegal, which have averaged 22% more yield in national trials over the last 3 years than the standard Senegalese variety Souna III, advanced to the prerelease stage in on-farm evaluation in that country.

Groundnut Advances

Our Groundnut Improvement Program, now well established in India, extended its efforts into Africa this year. We posted a breeder at the Chitedze Research Station, Lilongwe, Malawi, in September, to be joined in 1983 by a groundnut pathologist. They will develop a regional research program aimed at benefiting all the groundnut-growing areas of southern and eastern Africa.

Despite arriving late in the year, the breeder began planting ICRISAT materials in November, including 2000 breeding lines, breeding populations, germplasm lines, and elite parents. The team will conduct trials throughout southern Africa to produce groundnuts with multiple disease resistance, high yield, good food quality, earliness, and increased size. Their work will be valuable in Tanzania, Mozambique, Zambia, and Botswana, as well as in Zimbabwe and Malawi where much groundnut research has already been done.

The ICRISAT team was posted at the invitation of nine Heads of State in the Southern African Development Coordination Conference.

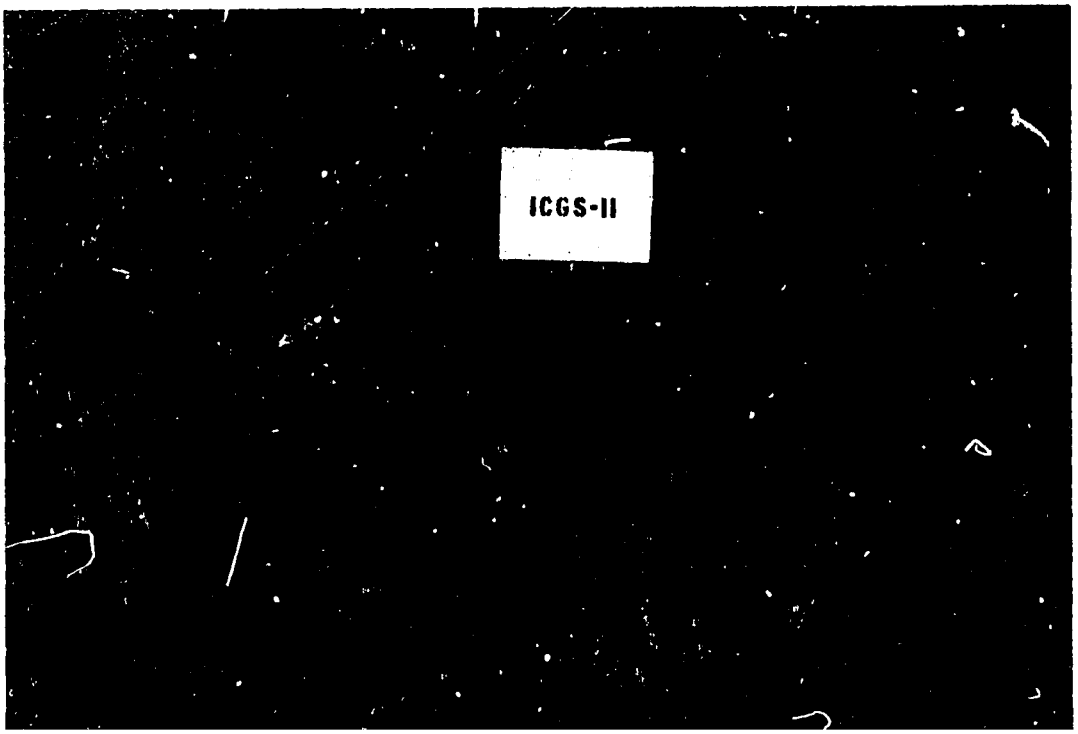
Our groundnut work in West Africa will be the responsibility of another team to be posted at the ICRISAT Sahelian Center in Niger.

The groundnut program at ICRISAT Center, Patancheru, distributed 4187 populations and breeding lines to 31 countries during 1982.

In India, four ICRISAT selections that performed consistently well in postrainy seasons advanced to the last stage of evaluation before release to farmers by the All India Coordinated Research Project on Oilseeds. Four other ICRISAT groundnut selections advanced to the Coordinated Variety Trial of the national program.

ICRISAT scientists discuss infected groundnut plants at the Rosette Disease Nursery in Lilongwe, Malawi. The Malawi regional program will focus on southern and eastern Africa.

Four ICRISAT groundnut selections, including ICGS 11, moved to the last stage of prerelease evaluation in India.



Chickpea Advances

Unfavorable weather conditions hampered research in 1982 at all three of the major locations where we work on chickpeas, but some significant achievements were still recorded.

At ICRISAT Center, where we research the short-duration desi types grown in southern and central India, the total annual rainfall of 1200 mm was 50% above normal. It interfered with seedbed preparation and led to poor plant emergence; poor stands were further reduced by collar rot and fusarium wilt, making interpretation of data difficult.

At Hissar, India, where we have a cooperative program with Haryana Agricultural University to work on the long-duration desi and kabuli types common to northern India and Pakistan, excessive rain during the growing season favored ascochyta blight and botrytis gray mold, which caused losses up to 50% in Punjab, India, and in Pakistan.

In Syria, where we work jointly with ICARDA on kabuli-type chickpeas for winter or spring sowing in the Mediterranean region and for South and Central America, growth of the winter crop was severely depressed by

Chickpea crop affected by ascochyta blight at Hissar, northern India. Excessive rains favored the blight and hampered chickpea research this year.

ICRISAT's high-yielding, medium-duration desi chickpea ICCC 4 is being considered for general cultivation in Gujarat, India. Several other ICRISAT cultivars performed well and moved ahead in tests.

the cool, dry conditions, and many genotypes previously considered relatively cold tolerant were badly damaged.

The continuing wet conditions favored development of ascochyta blight in both winter-sown and spring-sown chickpea, and many farmers growing traditional varieties plowed their crop under and replaced it with summer crops. These problems underscore the need for research to overcome such natural hazards.

Despite those negative conditions, there were important advances in 1982. An ICRISAT/ICARDA chickpea that has resisted ascochyta blight, ILC 482, fared better than local cultivars under severe conditions and has been released for winter sowing and general cultivation in the dry areas of Syria. Another cultivar from that program, ILC 484, is being multiplied for large-scale, winter-sown trials in Jordan.

Our high-yielding, medium-duration desi cultivar, ICCC 4, was under consideration for general cultivation in Gujarat, India, and we provided the highest yielding variety, P 326, in the Coordinated Variety Trials in the central zone of India, in which our ICCC 22 also performed well.

Two of our cultivars were accepted for initial evaluation in next year's trials and two others advanced to the next stage of testing.

Pigeonpea Advances

Our 5-year cooperative program with the University of Queensland, Australia, paid good dividends this year. A pigeonpea cultivar developed from a cross in our breeding program in India was released to Australian growers, under the name Hunt, after 3 years of testing in Queensland. It is relatively insensitive to photoperiod (the relative lengths of daylight and darkness that affect plant growth), flowers in about 65 days, and has brown seeds weighing approximately 10 grams per hundred. Plant populations of around 400 000 per hectare are required for maximum yield.

A fertile green pigeonpea field attests the success of ICRISAT's 5-year cooperative program with the University of Queensland in Australia.

The program developed an improved production system that uses early-maturing pigeonpea cultivars and offers outstanding yields. It consistently yielded 4000 to 6000 kg/ha during tests in Australia and exceeded 8000 kg/ha in two instances. The system has now been researched and accepted in Fiji. Its adoption is expected to make that country self-sufficient in pigeonpeas.

The University of Queensland staff also identified two new sources of genetic male sterility (a key element in breeding hybrids and producing their seed commercially) and developed photoperiod-insensitive and fast-ratooning lines. Genetic material from the program has been sent to many parts of the world.

Although ICRISAT's funding of the program formally terminated in November, the University of Queensland will continue the work under alternative funding.

The program at ICRISAT Center supplied 3302 pigeonpea samples to various breeders--2075 to scientists at 39 locations in India and 1227 to breeders in 28 other countries. The material included first- and second-generation lines, segregating progenies, advanced lines, disease-resistant lines, male-sterile stocks, and newly converted male-sterile progenies.

Research in 1981/82 demonstrated that as many as three harvests of pigeonpeas can be taken from one planting on deep black soils such as those normally left fallow in many parts of India during the rainy season. The key is using a pigeonpea that resists both wilt and sterility mosaic.

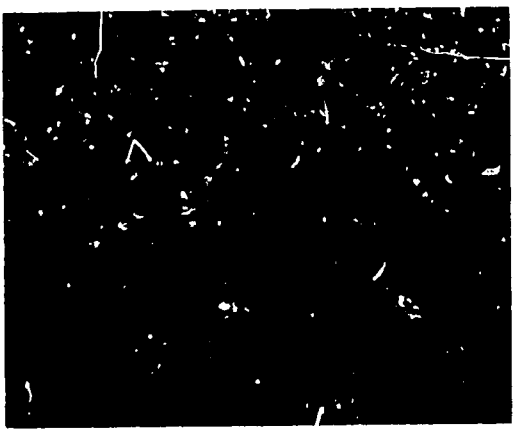
The three-harvest crop starts as a normal postrainy-season crop seeded in September

or October. The first harvest is in late February or March, with the ratooned plants left to quickly establish a full canopy—without expense for land preparation or planting—when the monsoon arrives. The second harvest is in December, with the third harvest from the same plants in March or April. Substantial firewood also may be removed, and about 40 kg/ha of nitrogen is added to the soil by fallen leaves.

We continued to obtain good pigeonpea hybrids using our recently developed male-sterile lines. One early hybrid, ICPH 8, which has been selected for the All India Coordinated Tests, yielded nearly 4000 kg/ha in northern India.

Growing pigeonpeas at a range of six sites in the Nilgiri and Palni Hills of southern India, we obtained seeds at one location in time enough to show that we can produce two generations in a year of our late-maturing breeding material. This can speed up our breeding of late-maturing pigeonpeas.

Hunt, the pigeonpea cultivar released to Australian growers, is high yielding and relatively insensitive to photoperiod.



The second harvest, by pod picking, in ICRISAT's three-harvest pigeonpea crop; ratooning the crop exploits a full canopy and increases yields.

Advances in Genetic Resources

A zera-zera sorghum landrace collected in Ethiopia was converted this year into a photoperiod-insensitive line at ICRISAT Center. A trainee from China examines the converted sorghum head.

During 1982 we collected 3172 new accessions--1202 in sorghum, 1048 in pearl millet, 239 in pigeonpea, 127 in chickpea, 300 in groundnut, and 256 in minor millets—from 9 countries and distributed more than 31 000 samples of germplasm in those crops to some 28 countries.

We successfully converted a photoperiod-sensitive zera-zera sorghum landrace collected in Gambela, Ethiopia, into a photoperiod-insensitive line, enabling us to combine in it such desirable traits as improved grain quality and quantity, and shorter plant height.

We identified four new cytoplasmic male-sterile lines from pearl millet germplasm collected in Botswana and Ghana.

A wild relative of pearl millet, with desirable large spikelets, collected in Sudan.

Chickpea germplasm assembled and grown at ICRISAT Center shows wide variability.

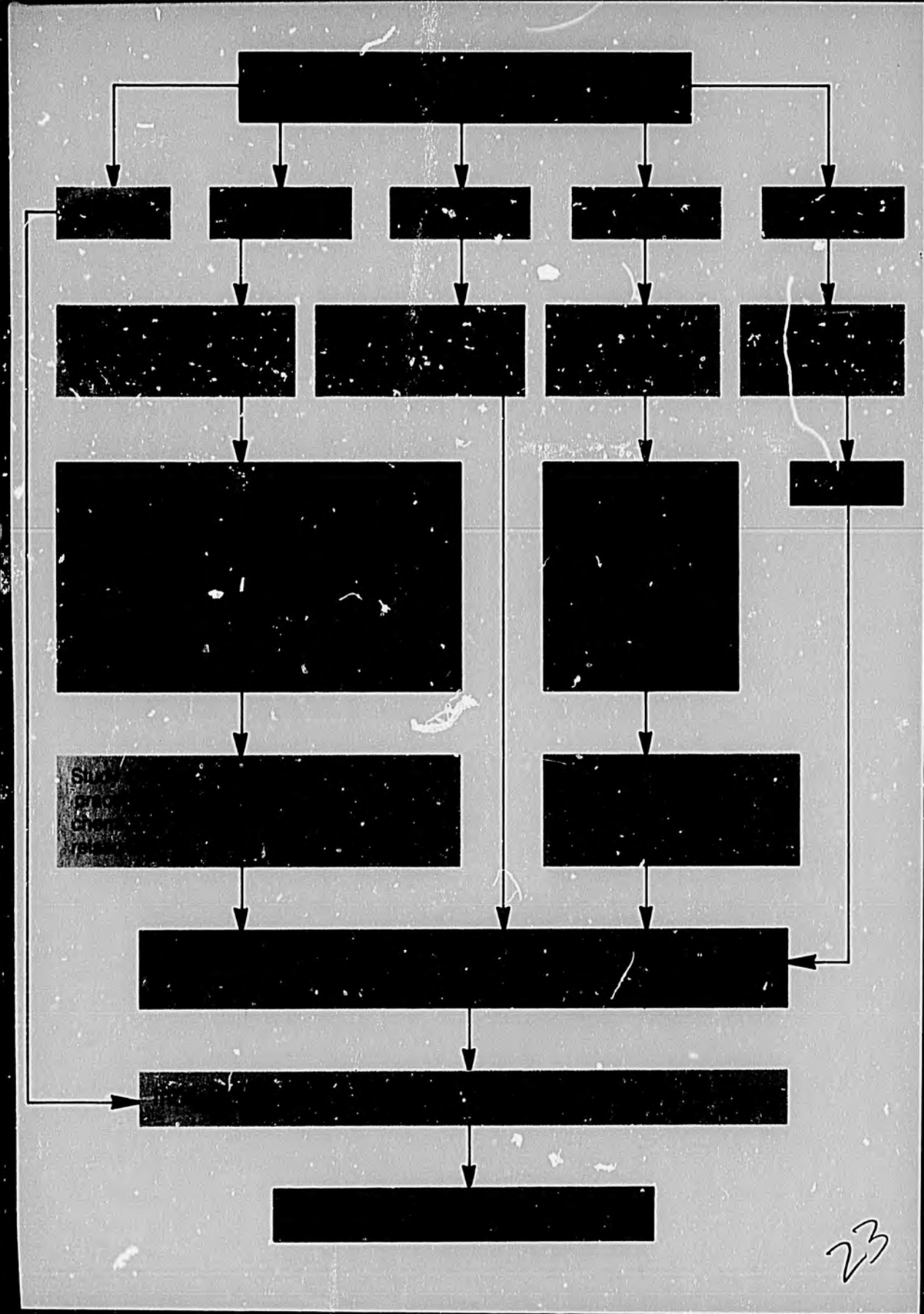
We collected new wild taxa of groundnut as well as relatively little-known germplasm, obtaining 37 wild accessions and 7 samples of cultivated groundnut on a joint collecting expedition in Brazil with EMBRAPA.

After several bad seasons under extended daylength, we successfully multiplied for the first time *Cicer yamashitae*, a wild relative of chickpea from Afghanistan. We also collected new large-seeded, late-maturing pigeonpea from Kenya, and produced new interspecific hybrids between pigeonpea and its relatives from Australia.

Overcoming the Yield Reducers

We had considerable success in 1982 in our work to control the diseases, insects, and other pests that reduce the yields of our five mandate crops throughout the semi-arid tropics. Pathologists, virologists, and entomologists are vital members of the interdisciplinary crop improvement teams working to develop high-yielding plant lines that will embody natural resistance to major diseases and pests.

We attempt to provide to collaborating scientists from national programs tested breeding materials with resistance to diseases and pests for their further testing,



selection, or use. We receive from them in turn valuable information on pathogens and insect pests in their countries.

The results of some of this work are reported below.

Resistance to Diseases

In Groundnuts

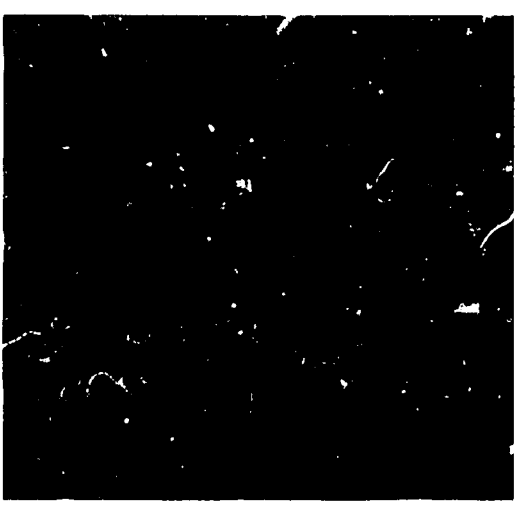
Eight of our genotypes that resist rust and late leaf spots yielded more than twice as much (1000 to 400 kg/ha) as any of three released cultivars under severe disease pressure in the 1982 rainy season.

Rust and leaf spots are major causes of yield losses in groundnuts in many parts of the world. At ICRISAT Center we continued to transfer characters from wild species, and began using derivatives from such species in breeding for resistance to those diseases.

Field trials at ICRISAT Center in 1981/82 confirmed that planting groundnuts denser and earlier reduces bud necrosis, and a survey of farmers' fields showed bud necrosis highest in fields with thin stands.

Fusarium wilt, a major disease of pigeonpea worldwide, is shown here in a farmer's field in Kenya.

Late leaf spots in groundnut: eight ICRISAT genotypes resisting this disease yielded 2½ times as much as released cultivars under severe pressure.



The establishment of a regional groundnut improvement program for southern Africa at Malawi in 1982 will enable us to study the rosette virus, which causes a disease specific to groundnuts in Africa. We will also place emphasis on combining resistances to rust, leaf spot, and rosette virus diseases.

In Pigeonpeas

ICRISAT's ICP 8863 pigeonpea resisted fusarium wilt at all 11 locations where it was tested in 1982, and has been recommended by the All India Coordinated Pulse Improvement Project for their breeding program to

develop wilt-resistant varieties. That disease causes immense losses to the crop in South Asia and Africa. We also showed that intercropping pigeonpea with sorghum greatly reduces wilt.

We supplied the All India Coordinated Pigeonpea Trials with 11 wilt-resistant and 14 sterility mosaic resistant lines that also possess good agronomic characters. Sterility mosaic is the chief disease of pigeonpea in India.

We selected for further testing 331 plants with multiple resistance to sterility mosaic, fusarium wilt, and phytophthora blight and identified a new isolate (P3) of phytophthora blight fungus that killed all the lines that resisted P2, the earlier known isolate. We have changed our priority accordingly.

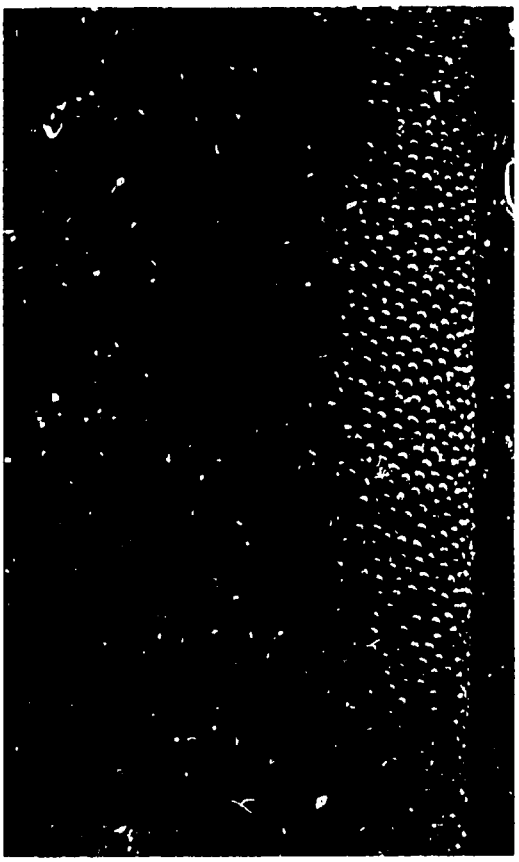
In Chickpeas

In addition to our work on ascochyta blight resistance (reported under 'Chickpea Advances') we made progress this year against fusarium wilt, the major disease of chickpea in Chile, Mexico, the USA, and in South Asia. We identified 28 new lines resistant to fusarium wilt and showed that resistance to the wilt is conferred by two recessive genes that separately delay wilting but must be present together for complete resistance.

We also standardized methods to screen for resistance to botrytis gray mold and identified 16 lines with resistance. Gray mold attacks chickpeas in areas of northeastern India and Bangladesh with humid growing seasons.

In Pearl Millet

Downy mildew is a devastating disease in pearl millet: it ruined the hybrid crop in India in the early 1970s and remains a constant menace to new cultivars. ICRISAT has been able over the years to develop and distribute breeding stocks with high levels of resistance to that disease; our first variety released in India, WC-C75, has that resistance as does ICMS 7703, a variety within one step of release.



ICRISAT's smut-resistant pearl millet contrasts with the diseased head at left. Many entries with low smut incidence were identified in this year's testing.

We developed a new seedling inoculation technique in 1982 to screen for downy mildew resistance in greenhouses or laboratories and began to use it in screening all breeding material. We also found that plants systemically infected with downy mildew can recover and produce healthy seeds if sprayed with metalaxyl, a systemic fungicide. This means the disease can be controlled after it has appeared in the field.

Eleven of 15 ICRISAT millet entries in the West Africa Disease Resistance Elite Varietal Trial were highly resistant to downy mildew, and all 15 had moderate resistance to ergot and smut.

In ICRISAT's 28-entry multilocational testing for smut across five locations, we identified 15 entries with less than 1% smut incidence; the other 13 had less than 7%, compared with 49% in the control cultivar in those tests.

Our improved screening techniques for all three major diseases of pearl millet—downy mildew, ergot, and smut—have enabled us to select for resistances to all within one generation.

In Sorghum

We can now screen effectively for resistance to grain molds, downy mildew, and anthracnose in sorghum, and we have improved our understanding of management factors relevant to screening for resistance to charcoal rot. This enables us to search more effectively for varieties with multiple resistance and to incorporate several new traits in improved varieties and hybrids.

Sources of resistance to downy mildew, a major fungal disease in sorghum as well as pearl millet, to *Striga* , a parasitic weed, and to shoot fly and midge, two important insect pests, are all now available in agronomically good varieties.

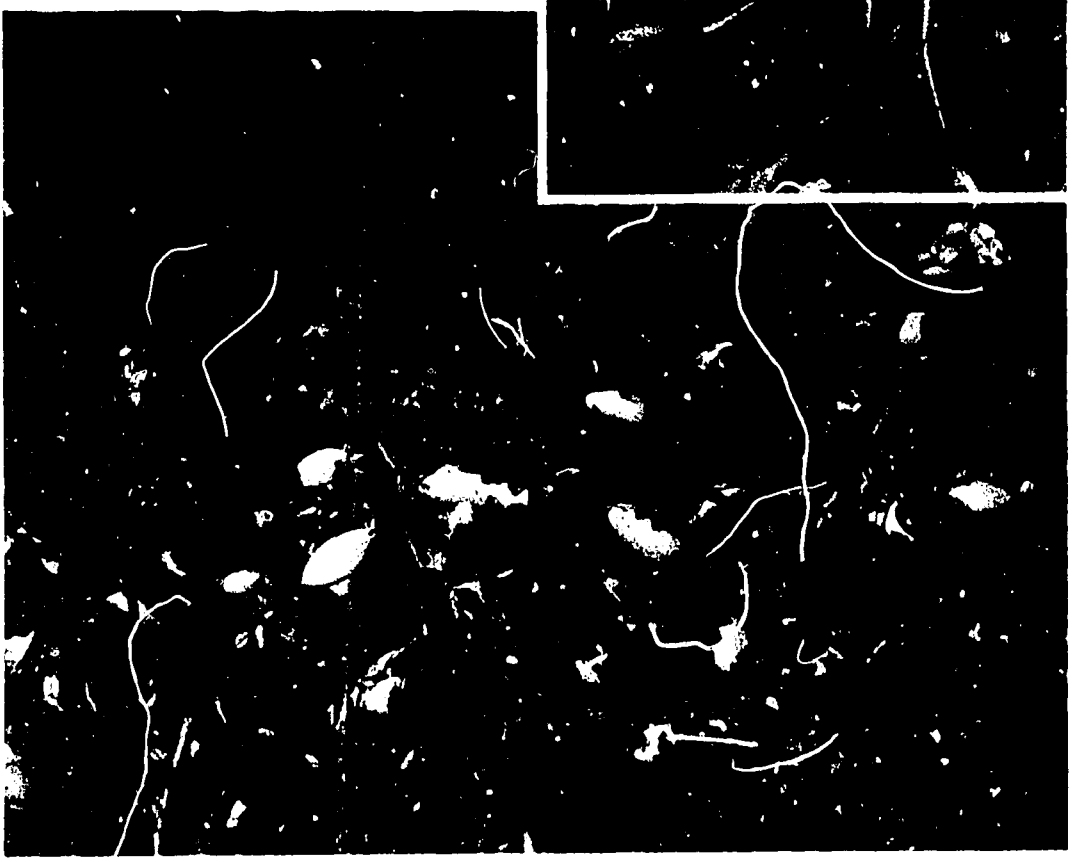
ICRISAT's E 35-1 sorghum, for example, now growing in Upper Volta, has shown resistance in international nursery tests to anthracnose, leaf blight, rust, zonate leaf spot, sooty stripe, rough leaf spot, and oval leaf spot.

During 1982, we completed tests enabling us to screen for charcoal rot without artificial inoculation.

We also identified 78 sorghum lines highly resistant to grain molds, and selected 33 of 6698 lines screened for anthracnose resistance at Pantnagar.

Screening for charcoal rot without inoculation: at left is resistant ICRISAT sorghum E 36-1, at right susceptible hybrid CSH 6.

The pod borer, Heliothis, *extensively damages chickpeas and pigeonpeas. At right, larvae feeding on pods; below, a plant damaged by the insects.*



Resistance to Insect Pests

In pulses, where the pod borer *Heliothis armigera* is a major threat, we confirmed sources of resistance to that pest in early-maturing chickpea lines this year and began transferring this quality to better adapted material. We achieved similar success, but to a lesser extent, in pigeonpea where *Heliothis* is even more destructive, especially in southern India.

In much of the world, sorghum midge (*Contarina sorghicola*) is a destructive pest of grain sorghum. Seven of ICRISAT's 10 midge-resistant breeding lines included in the International Sorghum Midge Nursery and the All India Coordinated Sorghum Improvement Project nurseries have shown high resistance—for 3 years in India and 2 years in Argentina. We obtained seed set of

Sorghum midge destroys the grain in much of the world. ICRISAT's resistant varieties are being tested in India, Argentina, and Upper Volta.

up to 90 to 95% with our resistant varieties under severe midge infestation in India, Argentina, and Upper Volta, where the local control had only 5% seed set.

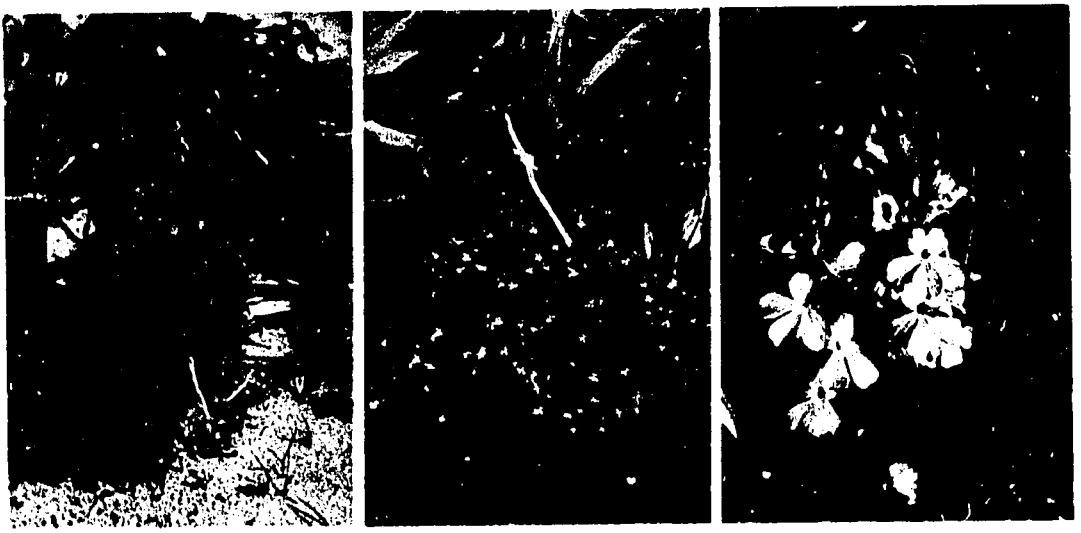
In Upper Volta, Thailand, and Nigeria, ICRISAT sorghums also did well under shoot fly attack.

ICRISAT's work on insect pests includes surveys, monitoring of pest populations in on-station crops or farmers' fields, study of biological control methods, including parasite and predator studies, and screening and breeding for resistance. Though we do carry out some studies relating to chemical control and methods of chemical application, insecticides receive a low priority in our research because farmers in regions where ICRISAT crops are grown use little or no insecticide.

Resistance to *Striga*

We made good progress this year against *Striga*, the parasitic witchweed that damages sorghum and millet.

Varying types of Striga. *The parasitic witchweed heavily damages sorghum and millet in Africa as well as in India.*



ICRISAT's Striga*-resistant sorghums grow on either side of a susceptible line.*

Our *Striga*-resistant SRN 4841 sorghum produced stable, high yields under improved management, including fertilizers and plowing, across all three ecological zones in Upper Volta—in farmers' fields in Yako, Nakomtenga, and Boromo. And a cross between SRN 4841 and a white-grained sorghum gave white-grained progenies that yielded well and resisted *Striga* in multilocation tests in Upper Volta.

We also have *Striga*-resistant sorghum varieties growing in other African countries (Ethiopia, Sudan) and *Striga* nurseries in Mali, Mauritania, Gambia, Ghana, Niger, and Cameroon.

Some of the best *Striga*-resistant varieties in Sudan were discovered to be so quite by accident in 1981 when a set of elite varieties in a yield trial at Kagugli was inadvertently planted in a *Striga*-infested field. Yields from the set showed good tolerance to *Striga* while those in neighboring plots showed high susceptibility. We tested them again this year and confirmed that three of the varieties have much stronger resistance to *Striga* than two other lines previously identified as resistant.

In India, three ICRISAT sorghum varieties, SAR 1, SAR 2, and SAR 16, significantly outyielded all other varieties and hybrids in areas where *Striga* infestation is severe. We also identified for further testing another set of eight breeding lines with good field resistance.

A seed-pan technique that we developed enables us to screen individual plants for *Striga* resistance when sorghum seedlings are 55 days old. We are refining this technique to reduce the days required and to make the technique nondestructive.

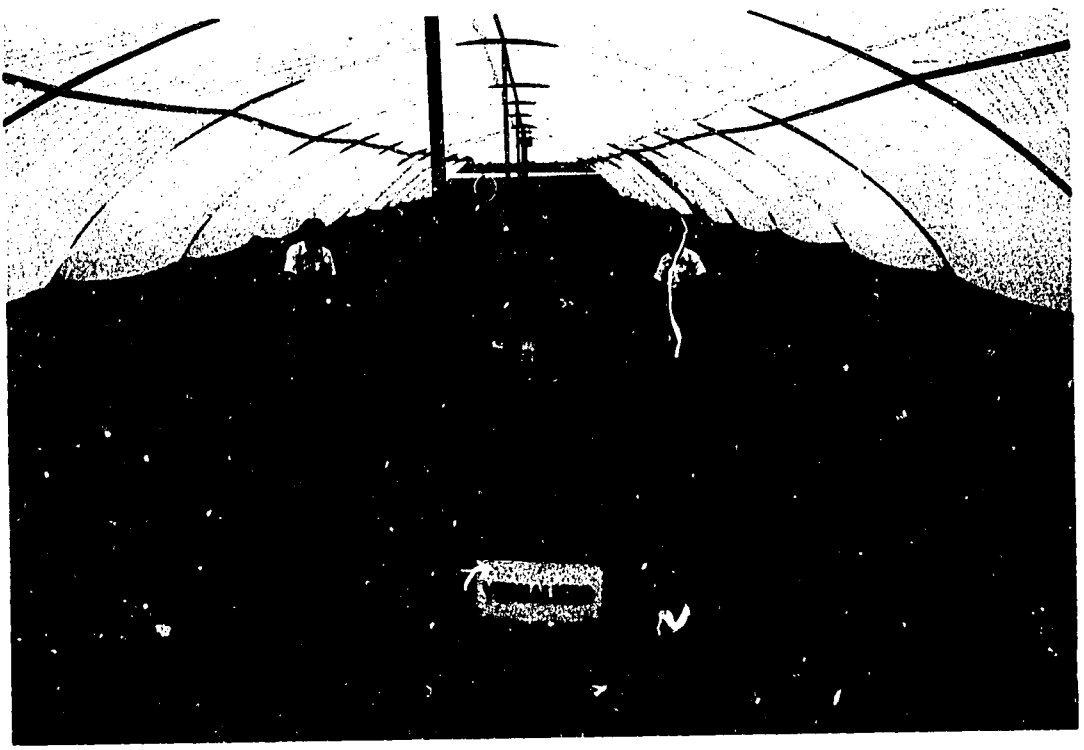
Overcoming Drought and Other Stresses

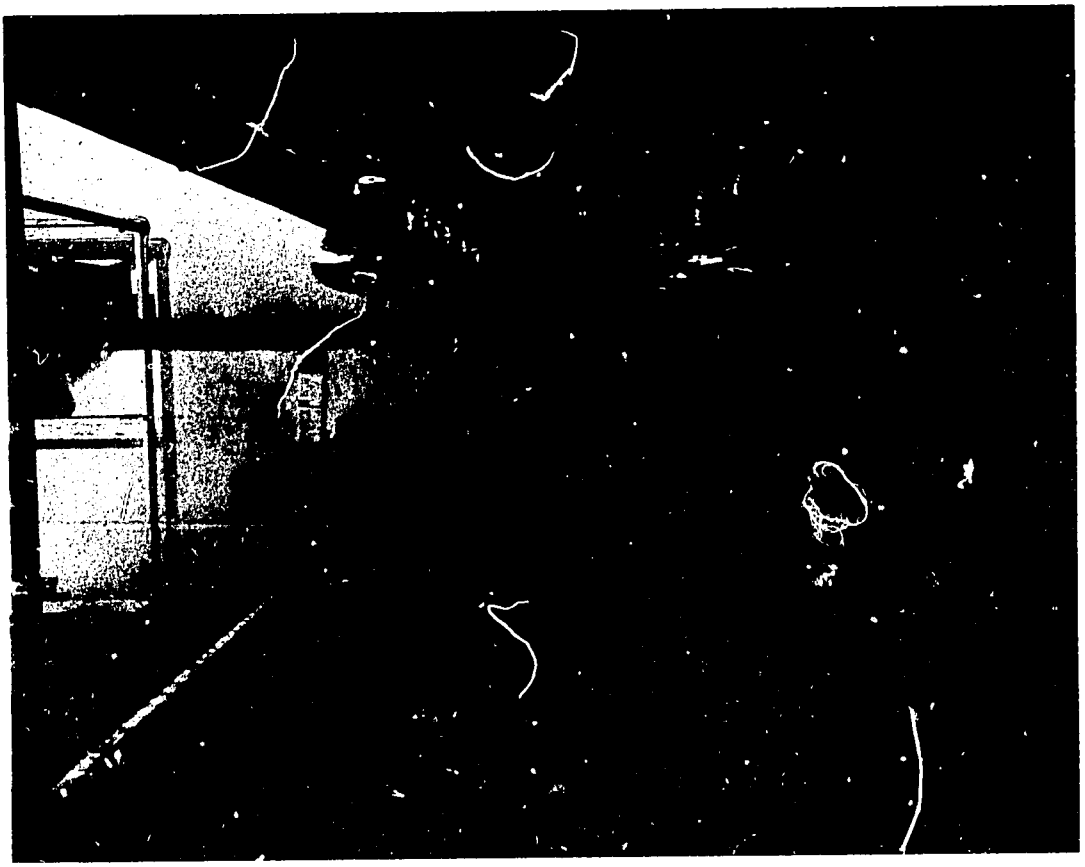
Extremes of environmental stress—from drought, high temperatures, or marginal soil fertility—are typical of the semi-arid tropics. ICRISAT scientists routinely study crop behavior under those conditions to identify sources of resistance and incorporate them in new lines.

Such study may involve developing techniques to apply controlled and repeatable physical stresses to breeding materials, or testing materials under actual stress environments. It often means finding parent stocks in germplasm that can withstand the harsh conditions of the SAT and grow well in farmers' fields. Breeding for a range of growth durations—which involves shortening or adding to the period a crop needs to mature to suit varying agroclimatic factors—is also a component of this research.

In sorghums this year, we had six drought-resistant breeding lines that yielded 2 to 3 times more than the recommended control

Photoperiod studies in chickpea form part of ICRISAT's work on combating physical stresses. Lamps at far end are used to extend daylight for the plants.





Studying how seedlings emerge under high soil temperatures is an important part of research at ICRISAT Center.

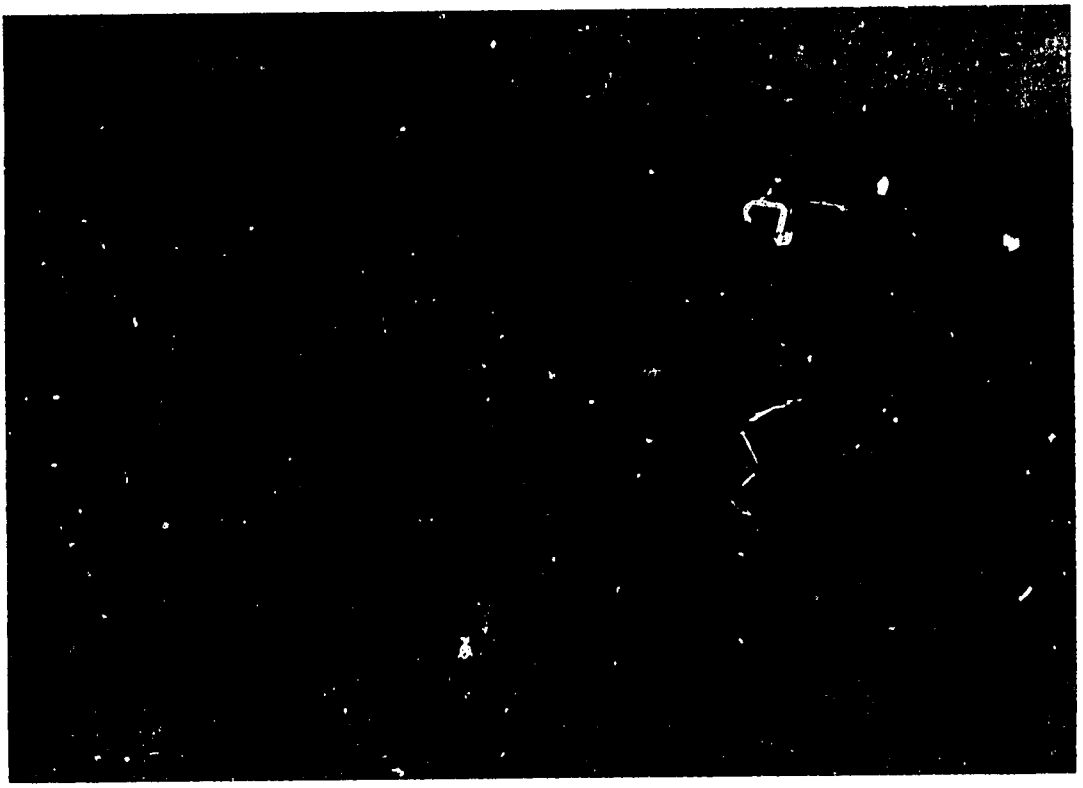
cultivar (430 to 630 kg/ha, compared with 220 kg/ha) during severe drought at Anantapur in southern India. In Upper Volta also, four of our varieties significantly outyielded local sorghums under severe drought pressure.

At three locations in India, ICRISAT's dry-season sorghum D71240 averaged 2900 kg/ha, compared with 1900 kg/ha for Maldandi, the popular local dry-season variety. In an advanced yield trial at Bijapur, Karnataka, and at ICRISAT Center, 12 of the 36 ICRISAT entries substantially outyielded the local control, M 35-1.

We also developed a technique to study seedling-emergence response to high soil temperatures with no drought stress; this can be used to screen genotypes being used in sorghum and millet improvement programs.

In groundnut, we identified several drought-resistant genotypes that yielded more than 1000 kg/ha under drought stress, compared with 500 to 800 kg/ha by released cultivars during the 1982 rainy season at Anantapur in southern India.

Studying drought stress at various stages of growth in groundnut at ICRISAT Center,



Trial plots at ICRISAT Center showing differences in drought stress in groundnut, induced by varying irrigation treatments.

we found that drought stress from pod filling to maturity reduced yields most, but that stress from emergence to pegging could increase yields.

In studying how chickpeas react to light, cold, and moisture as part of determining their adaptability and yields, we found that low temperatures, less light, and high soil moisture cause the formation of pseudoflowers and the abortion of flowers.

Using a red soil of low water-holding capacity, we developed a screening technique for identifying chickpea cultivars that can grow under both drought stress and irrigation. While the growth duration of a cultivar is known to be a major factor in yield under drought conditions, we also found differences among cultivars with a similar maturity period. These will be studied further.

Thus, effective solutions to the common problems of crop survival under physical stresses of different kinds are beginning to emerge in ICRISAT's multidisciplinary research. And the knowledge acquired is readily applicable in both national and international crop improvement programs in the SAT.

Using Nitrogen from the Air

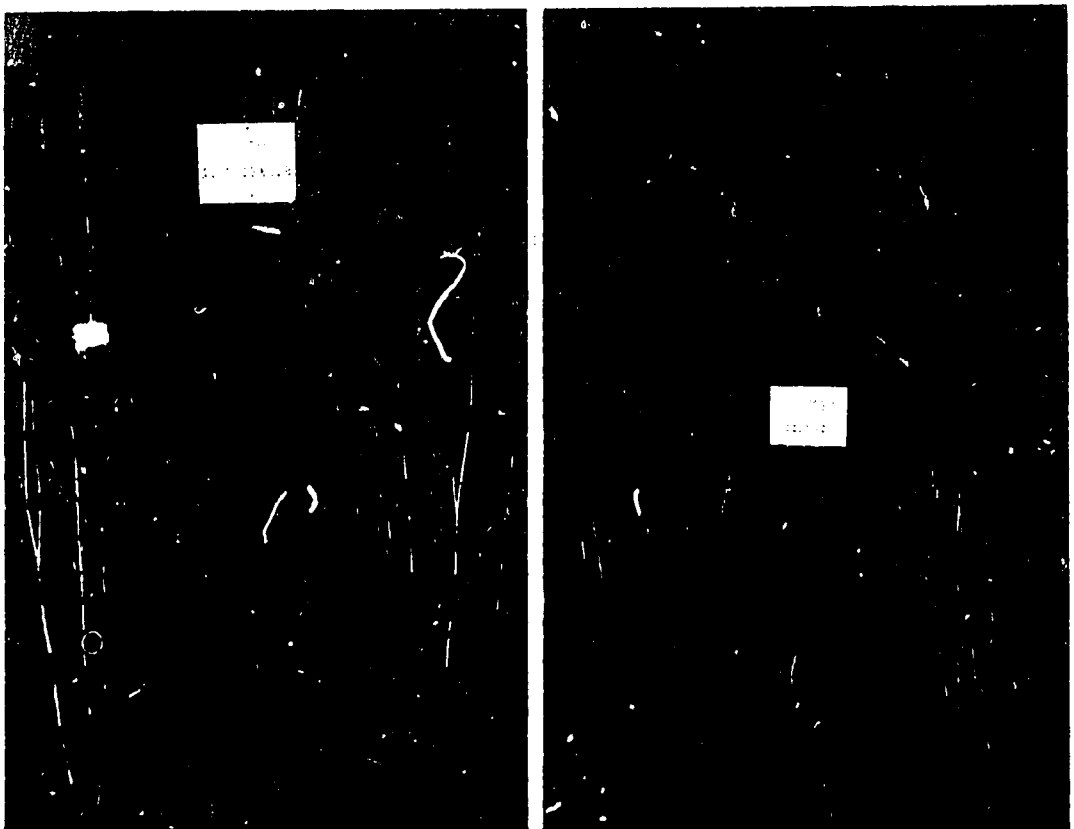
Low nitrogen availability in the soil is a factor limiting production in many parts of the SAT, and fertilizers are seldom within reach of poorer farmers. Using the knowledge that legumes and, in a less obvious fashion, cereals and grasses are able to fix atmospheric nitrogen in their roots, the microbiologists in our crop improvement programs try to estimate such nitrogen fixation in different germplasm lines and cultivars. They thus identify lines that may have higher levels of nitrogen-fixing activity and can be used in further selection and breeding.

In legumes, the nitrogen fixation is achieved in root nodules, where nitrogen-fixing bacteria live in a symbiotic relationship with the plants, providing them with at least some of their own nitrogen requirement by "fixing" it from the air. In cereals, such activity in the root zone is less visible but probably just as associative, often governed by bacteria acting as intermediary agents.

Inoculating plant roots with suitable bacteria has been shown to increase nitrogen fixation and, in some instances, yields. Our microbiologists study closely the components of this association and develop improved screening techniques that refine such studies. We made progress on all these fronts in 1982.

In pearl millet, we established in field trials that inoculation of cultivar IP 2787 with *Azospirillum lipoferum* increased the yield 17%, while inoculating hybrid BJ 104 with various

Inoculating pearl millet with suitable nitrogen-fixing bacteria increased yields (left); the crop at right was not inoculated.



nitrogen-fixing bacteria increased yields 12 to 25%.

We developed a nondestructive tube-culture assay technique to estimate nitrogenase activity of millet plants, enabling us to detect differences among genotypes 15 to 20 days after planting.

We improved our soil-core assay technique for estimating nitrogenase activity of field-grown millet and sorghum plants. By growing plants with their roots enclosed by the core—15 days after planting for millet and 21 to 30 days after planting for sorghum—we detected nitrogenase activity 10 to 23 times that recorded using the normal core assay.

In another experiment, we used nitrogen gas enriched by $^{15}N_2$ to show that nitrogen fixed in the root zone of 25-day-old sorghum seedlings is transferred to the shoots within 7 days.

In groundnuts, we confirmed our earlier field-trial observations of positive interaction between cultivar Robut 33-1 and *Rhizobium* strain NC 92, and identified two other cultivars, JL 24 and ICGS 27, which gave higher yields when inoculated by that strain.

We also identified groundnut germplasm line NC Ac 2821 as having good potential in breeding for nitrogen fixation. In trials at ICRISAT Center, that line showed good combining ability for traits associated with nitrogen fixation.

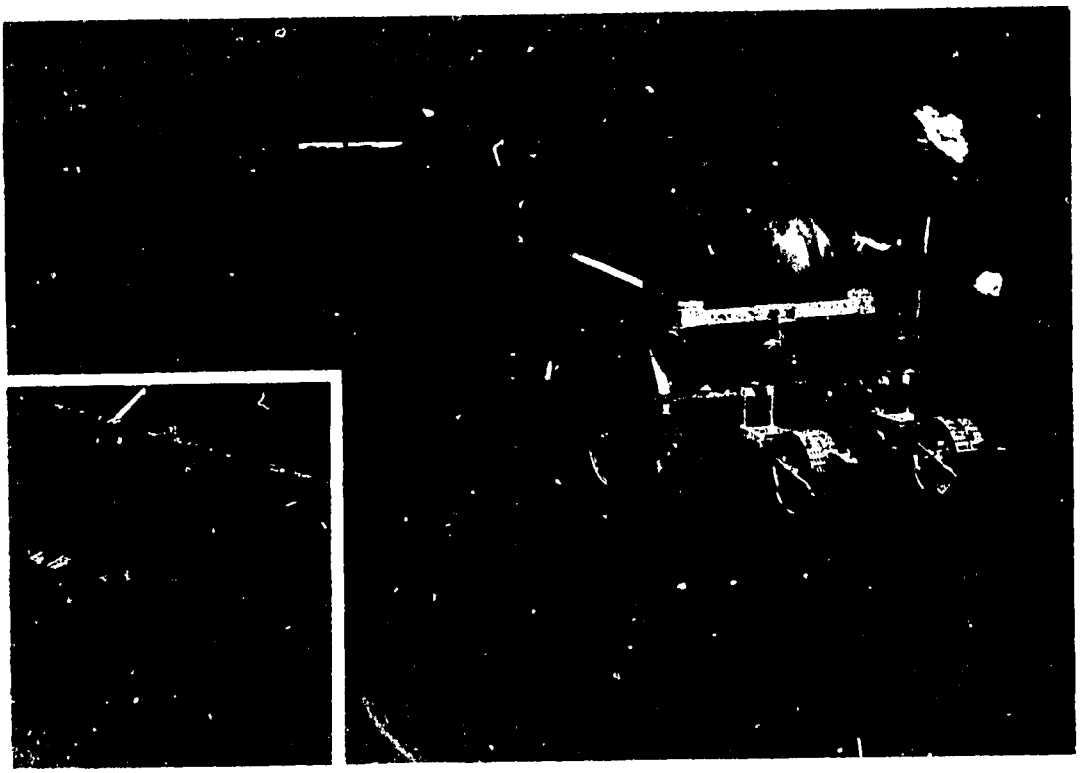
We estimated, by using ammonium sulphate labeled with ^{15}N in a Vertisol, that more than 80% of pigeonpea's nitrogen requirement was derived from biological fixation.

In chickpeas, we found that rhizobia applied to seed coats do not reach the root zone without rain or irrigation, and that alternative inoculation methods are needed for crops grown primarily on moisture remaining after the rainy season.

These findings will be used to develop more effective ways to exploit the nitrogen available in the air, by selecting cultivars and germplasm lines for that trait, by identifying strains effective as inoculants, and by developing new inoculation techniques.

Plant roots are exposed to labeled nitrogen gas in efforts to study nitrogen-fixing activity in the root zone.

Improving Farm Equipment



The rolling crust breaker at work with the bullock-drawn wheeled tool carrier: inset shows sun-hardened crust of soil broken by the operation.

An important part of ICRISAT farming systems work is in designing or modifying equipment that will aid the small farmer. This year we developed two models of a rolling crust breaker, one to be operated by hand and one for use on an animal-drawn wheeled tool carrier.

They can be useful in breaking the sun-hardened crust of soil that greatly reduces emergence of seedlings, a common problem in the semi-arid tropics. In the tests at ICRISAT Center, only one of 10 pearl millet genotypes exceeded 4% emergence through a crust, compared with 23 to 55% when the crust breaker was used. With sorghum, 96% of the seedlings emerged with the crust broken, compared with only 36% through a crust.

The crust breaker was used to break through the hard covering of seeded rows the day before plants were expected to emerge.

Our engineers also designed a furrow opener requiring relatively low draft that can place seed and fertilizer 10 to 12 cm deep, acceptably separated, and that does not clog easily in wet soil.

Training Activities

One of the most important aspects of our work at ICRISAT Center each year is the training of agricultural scientists and technical assistants who come from many countries to learn about our research and to sharpen their own skills. Many of those who have completed training since 1974 are now serving as farm managers, leaders of research teams, field technicians, and extension agents.

A total of 126 persons from 35 countries completed our training programs in 1982. There were 11 who completed postdoctoral work, and of the 32 students from 11 countries engaged in thesis research, 16 completed work for their Ph.D. and M.Sc. degrees under the guidance of our scientists.

An in-service fellow program was initiated to provide opportunities for employed research scientists with experience in the semi-arid countries to obtain intensive training in their specialties. Seven fellows from four countries participated in the first year of that program.

ICRISAT breeder (left) helps trainee from Jordan identify chickpea wilt.

In-service trainees from Sudan score sorghum heads for grain mold.

The annual 6-month in-service training program for scientists and technical assistants accommodated 91 persons from 29 countries; 90 ICRISAT scientists helped train them.

In addition to the long-term training offered in those programs, we conducted short-term training at ICRISAT Center for agricultural officers, policymakers, and bank officers to help them transfer and apply the technology we have developed for double cropping the deep black soils of India.

Our training in other countries included 15 scientists who worked with our sorghum breeder and agronomist posted in Mexico, and Malian students who worked on their theses with our agronomist and cereals breeder in Mali for later employment by their government as agricultural research scientists.

Trainee from Malawi studies growth pattern in chickpea/pigeonpea intercropping experimnent at ICRISAT Center.

Access Roads and "Balanced" Nutrition

Going to market: economic studies show that improving access to markets increases farm production.

Adding roads and markets, particularly reducing distance to the market, will increase farm production. Our economists base this finding on 20 years' official statistics from 94 districts in four states of India, supplemented by a survey of 600 farmers.

As market access improves, owners of large farms would benefit most initially, but medium-sized and small farmers would benefit more later and contribute more to production after they adjusted to the improved market conditions.

Providing market access at a rapid rather than a slow rate would thus combine higher production with more equitable distribution of benefits.

In another study analyzing economic conditions in Indian villages, we found a logical reason for adult males eating more than their share of scarce family food. Wages in Indian villages, our economists found, go up more with the weight and height of males than with their education. Thus, to support one's family, it is important to remain healthy and keep one's weight up.

The ICRISAT study concluded that food programs aimed at vulnerable persons, such as infants and pregnant women, may succeed only when they provide enough food for the wage earner as well.

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J. S. Kanwar, Director of Research (on sabbatic leave from Apr 1982)
R. W. Gibbons, Director of Research (from Apr 1982)
J. C. Davies, Director for International Cooperation (until Aug 1982)
M. G. Wedeman, Principal Administrator
S. S. Dhanoa, Special Assistant to Director General and Principal Government Liaison Officer
B. C. G. Gunasekera, Principal Soil and Water Scientist, International Cooperation
N. Patterson, Special Assistant to Director General for Educational Affairs
V. Balasubramanian, Executive Assistant to Director General
Joyce Gay, Administrative Secretary to Director General
Sunetra Sagar, Administrative Secretary to Director of Research
S. Krishnan, Executive Assistant (International Cooperation)
D. Mitra, Fiscal Manager
A. Banerji, Assistant Manager (Fiscal)
V. S. Swaminathan, Accounts Officer
A. N. Venkatswamy, Accounts Officer
B. K. Johri, Personnel Manager
P. Suryanarayana, Personnel Officer
N. S. L. Kumar, Personnel Officer
R. Vaidyanathan, Purchase and Stores Manager
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K. P. Nair, Purchase Officer
D. K. Mehta, Stores Officer
D. V. Rama Raju, Purchase Officer
K. C. Saxena, Stores Officer
S. K. Dasgupta, Scientific Liaison Officer (Visitors' Services)
A. Lakshminarayana, Scientific Liaison Officer (Visitors' Services)
N. Rajamani, Travel Officer
R. Narsing Reddy, Transport Officer
K. K. Sood, Security Officer
K. K. Vij, Executive Assistant (Liaison), Delhi Office
V. Lakshmanan, Executive Assistant
N. Suryaprakash Rao, Resident Medical Officer
P. Subrahmanyam, Administrative Assistant

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M. Tardieu, Coordinator of Programs, West Africa (from Nov 1982)
K. F. Nwanze, Principal Millet Entomologist and Acting Team Leader, Niger
K. Anand Kumar, Principal Millet Breeder, Niger (from Feb 1982)
B. B. Singh, Principal Millet Breeder, Niger (Maradi)
L. K. Fussell, Principal Millet Agronomist, Niger
E. J. Guthrie, Principal Millet Pathologist, Niger
J. McIntire, Principal Economist, Niger
C. M. Pattanayak, Principal Sorghum Breeder/ Team Leader, Upper Volta (on sabbatic leave until Sept 1982)
A. J. Dagenais, Administrative Officer, Upper Volta
K. V. Ramaiah, *Striga* Physiologist, Upper Volta
S. N. Lohani, Principal Millet Breeder, Upper Volta
E. R. Perrier, Principal Agronomist, Soil and Water Management, Upper Volta
P. J. Matlon, Principal Production Economist and Acting Team Leader, Upper Volta
Helga Vierich, Principal Social Anthropologist, Upper Volta
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J. F. Scheuring, Principal Cereals Breeder, Mali
P. G. Serafini, Principal Cereals Agronomist, Mali
S. O. Okiror, Principal Millet Breeder, Team Leader, Nigeria
N. G. P. Rao, Regional Sorghum Breeder, Nigeria
J. H. MacFarlane, Principal Cereals Entomologist, Nigeria
Brhane Gebrekidan, ICRISAT/SAFGRAD Coordinator for Sorghum and Millet, Eastern and Southern Africa, Kenya (from Sept 1982)
R. P. Jain, Principal Millet Breeder, Sudan
Gebisa Ejeta, Principal Sorghum Breeder, Sudan
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V. Y. Guiragossian, Principal Sorghum Breeder, Mexico

C. Paul, Principal Sorghum Agronomist, Mexico (from Sept 1982)
K. B. Singh, Principal Chickpea Breeder, Syria
M. V. Reddy, Principal Chickpea Pathologist, Syria

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S. Z. Mukuru, Principal Plant Breeder
L. K. Mughogho, Principal Plant Pathologist
J. M. Peacock, Principal Plant Physiologist
K. Leuschner, Principal Cereal Entomologist
T. Omori, Principal Sorghum Breeder, Visiting Scientist
Bhola Nath Verma, Plant Breeder
D. S. Murty, Plant Breeder
B. L. Agrawal, Plant Breeder
B. V. S. Reddy, Plant Breeder
M. J. Vasudeva Rao, Plant Breeder
N. Seetharama, Plant Physiologist
R. K. Maiti, Plant Physiologist
Suresh Pande, Plant Pathologist
R. Bandopadhyay, Plant Pathologist
S. L. Taneja, Entomologist
H. C. Sharma, Entomologist
S. P. Jaya Kumar, Administrative Assistant

Pearl Millet

D. J. Andrews, Principal Plant Breeder and Leader
L. A. Hunt, Principal Plant Breeder (from Sept 1982)
F. R. Bidinger, Principal Plant Physiologist
R. J. Williams, Principal Plant Pathologist
P. J. Dart, Principal Cereal Microbiologist
K. N. Rai, Plant Breeder
B. S. Talukdar, Plant Breeder
Pheru Singh, Plant Breeder
S. B. Chavan, Plant Breeder
G. Alagarswamy, Plant Physiologist
V. Mahalakshmi, Plant Physiologist
P. Soman, Plant Physiologist
S. D. Singh, Plant Pathologist
R. P. Thakur, Plant Pathologist
S. P. Wani, Microbiologist
D. B. Godse, Microbiologist (until Feb 1982)
K. R. Krishna, Microbiologist
Nirmala Kumar, Administrative Secretary

Pulses

Y. L. Nene, Principal Plant Pathologist and Leader (on sabbatic leave from Apr 1982)
D. G. Faris, Principal Plant Breeder, Pigeonpea and Leader (Apr-Oct 1982)
W. Reed, Principal Entomologist and Leader (from Oct 1982)
J. B. Smithson, Principal Plant Breeder, Chickpea
J. A. Thompson, Principal Pulse Microbiologist
D. Sharma, Senior Plant Breeder, Pigeonpea
K. C. Jain, Plant Breeder, Pigeonpea
K. B. Saxena, Plant Breeder, Pigeonpea
L. J. Reddy, Plant Breeder, Pigeonpea (until Oct 1982)
S. C. Gupta, Plant Breeder, Pigeonpea
G. K. Bhatia, Plant Breeder, Pigeonpea (until May 1982)
Onkar Singh, Plant Breeder, Chickpea
C. L. L. Gowda, Plant Breeder, Chickpea
S. C. Sethi, Plant Breeder, Chickpea
Jagdish Kumar, Plant Breeder, Chickpea
N. P. Saxena, Plant Physiologist
Y. S. Chauhan, Plant Physiologist
S. S. Lateef, Entomologist
S. Sithanantham, Entomologist
C. S. Pawar, Entomologist
S. P. S. Beniwal, Senior Plant Pathologist
M. P. Haware, Plant Pathologist
J. Kannaiyan, Plant Pathologist
O. P. Rupela, Microbiologist
J. V. D. K. Kumar Rao, Microbiologist
D. M. Pawar, Senior Supervisor
M. D. Gupta, Senior Research Technician/ Senior Supervisor

Groundnut

R. W. Gibbons, Principal Plant Breeder and Leader (until May 1982)
D. McDonald, Principal Plant Pathologist and Leader (from May 1982)
D. V. R. Reddy, Principal Plant Virologist
J. H. Williams, Principal Plant Physiologist
J. P. Moss, Principal Cytogeneticist
K. Tanaka, Principal Plant Pathologist, Visiting Scientist
A. M. Ghanekar, Plant Virologist
L. J. Reddy, Plant Breeder (from Nov 1982)
P. Subrahmanyam, Plant Pathologist

V. K. Mehan, Plant Pathologist
P. T. C. Nambiar, Microbiologist
P. W. Amin, Entomologist
A. K. Singh, Cytogeneticist
D. C. Sastry, Cytogeneticist
S. L. Dwivedi, Plant Breeder
S. N. Nigam, Plant Breeder (until Aug 1982)
R. C. Nageswar Rao, Plant Physiologist
A. B. Mohammed, Entomologist
Mohinder Pal, Plant Physiologist
Y. Bhaskar, Assistant Engineer

Farming Systems

S. M. Virmani, Principal Agroclimatologist and Leader
R. W. Willey, Principal Agronomist (on Sabbatic leave from Mar 1982)
J. T. Moraghan, Principal Soil Scientist (until Mar 1982)
C. W. Hong, Principal Soil Scientist (from May 1982)
S. A. El-Swaify, Principal Soil Scientist (from July 1982)
G. E. Thierstein, Principal Agricultural Engineer
J. R. Burford, Principal Soil Chemist
S. M. Miranda, Principal Soil and Water Engineer
M. V. K. Sivakumar, Principal Agroclimatologist
Y. Nishimura, Principal Assistant Agronomist
R. Busch, Principal Soil Scientist
M. Wurzer, Principal Assistant Soil Scientist
S. V. R. Shetty, Agronomist
Piara Singh, Soil Scientist
Sardar Singh, Soil Scientist
T. J. Rego, Soil Scientist
K. L. Sahrawat, Soil Chemist
A. K. S. Huda, Agroclimatologist
M. R. Rao, Agronomist
M. Natarajan, Agronomist
V. S. Bhatnagar, Entomologist (until Oct 1982)
R. C. Sachan, Agricultural Engineer
P. Pathak, Agricultural Engineer
P. N. Sharma, Agricultural Engineer (until Apr 1982)
K. L. Srivastava, Agricultural Engineer
R. K. Bansal, Agricultural Engineer
J. Hari Krishna, Agricultural Engineer (until Feb 1982)
Ranjodh Singh, National Research Fellow (until Mar 1982)
S. K. Sharma, Senior Research Technician
Siloo Nakra, Executive Assistant
Surendra Mohan, Administrative Assistant

Economics

J. G. Ryan, Principal Economist and Leader (until Mar 1982)
M. von Oppen, Principal Economist and Leader (from Mar 1982)
V. S. Doherty, Principal Social Anthropologist (until Nov 1982)
T. S. Walker, Principal Economist
N. S. Jodha, Senior Economist
R. D. Ghodake, Economist
R. P. Singh, Economist
K. N. Murthy, Economist
K. G. Kshirsagar, Senior Research Technician
R. S. Aiyer, Administrative Assistant

Support Programs

Biochemistry

R. Jambunathan, Principal Biochemist
Umaid Singh, Biochemist
V. Subramanian, Biochemist

Genetic Resources

M. H. Mengesha, Principal Germplasm Botanist and Leader
L. J. G. van der Maesen, Principal Germplasm Botanist
K. E. Prasada Rao, Botanist
S. Appa Rao, Botanist
R. P. S. Pundir, Botanist
P. Remanandan, Botanist
V. Ramanatha Rao, Botanist

Plant Quarantine

B. K. Varma, Plant Quarantine Officer (from Jun 1982)
Upendra Ravi, Senior Technician

Fellowships and Training

D. L. Oswalt, Principal Training Officer
A. S. Murthy, Senior Training Officer
B. Diwakar, Training Officer
T. Nagur, Training Officer
A. Prakash Rao, Training Officer (from Mar 1982)

Information Services

H. L. Thompson, Head
Gloria Rosenberg, Research Editor
J. B. Wills, Research Editor
C. A. Giroux, French Writer/Editor
T. A. Krishnamurthi, Executive Assistant
S. M. Sinha, Art and Production Supervisor
S. Varma, Editor/Writer
H. S. Duggal, Chief Photographer
G. K. Guglani, Senior Artist
T. R. Kapoor, Senior Compositor
P. E. Stephen, Printshop Supervisor

Statistics

B. Gilliver, Principal Statistician
Murari Singh, Statistician (from Mar 1982)

Computer Services

J. W. Estes, Computer Services Officer
S. M. Luthra, Assistant Computer Services Officer
T. B. R. N. Gupta, Computer Programmer/Analyst
J. Sai Prasad, Computer Programmer/Analyst

Library and Documentation Services

S. Dutta, Librarian
P. K. Sinha, Documentation Officer
P. S. Jadhav, Assistant Librarian
S. Prasannalakshmi, Assistant Librarian

Housing and Food Services

A. G. Fagot, Manager
S. Mazumdar, Assistant Manager (Food Services)
B. R. Revathi Rao, Assistant Manager (Housing)
D. V. Subba Rao, Officer in Charge (Warehouse)

Physical Plant Services

E. W. Nunn, Station Manager
F. J. Bonhage, Construction Supervising Officer
P. M. Menon, Executive Assistant
B. K. Sharma, Senior Engineer (Mechanical)
Sudhir Rakhra, Senior Engineer (Civil)
D. Subramanyam, Senior Engineer (Electrical)
U. B. Culas, Manager (Workshop) (from Oct 1982)
S. K. V. K. Chari, Senior Engineer (Electronics and Instrumentation)
A. R. Das Gupta, Engineer (Communication)
D. C. Raizada, Engineer (Airconditioning)
N. V. Subba Reddy, Senior Supervisor (Landscaping)
D. V. S. Verma, Senior Supervisor (Machineshop)
R. Thiyagarajan, Senior Supervisor (Auto)
A. N. Singh, Senior Supervisor (Heavy Equipment and Tractors)
C.P. Rajagopalan, Accounts Officer

Farm Development and Operations

D. S. Bisht, Farm Manager
S. N. Kapoor, Senior Engineer (Farm Operations)
S. K. Pal, Plant Protection Officer
K. Ravindranath, Engineer (Farm Machinery)
M. Prabhakar Reddy, Senior Supervisor (Irrigation)
M. C. Ranganatha Rao, Assistant Engineer
K. Santhanam, Executive Assistant