PN-AAQ-697

ICRISAT Research Highlights 1983

International Crops Research Institute for the Semi-Arid Tropics

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Cover: Susceptible and drought-resistant sorghum genotypes at ICRISAT Center, 1983.

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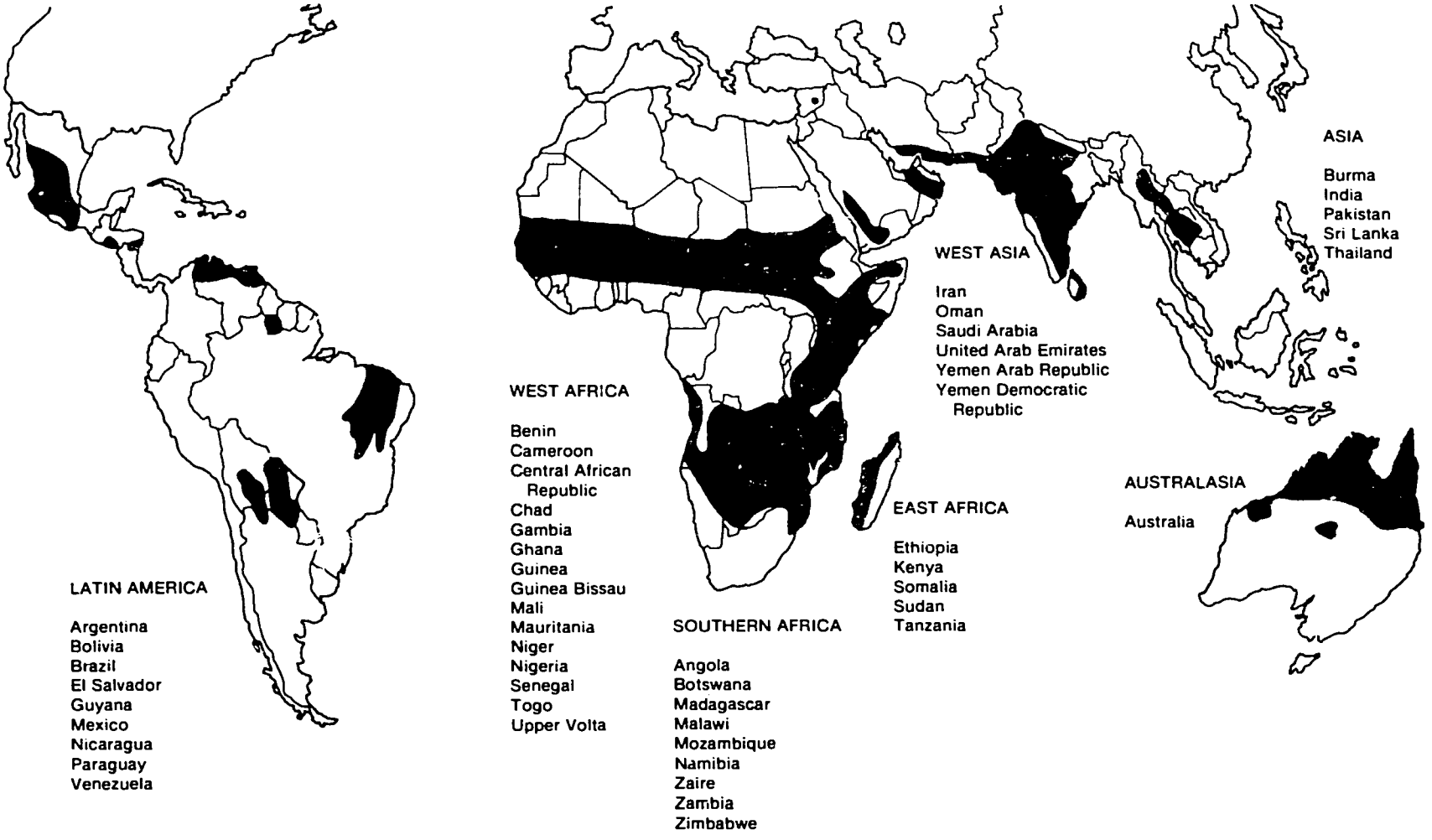


Semi-arid areas (in yellow) covered by ICRISAT's mandate. Green squares indicate location of ICRISAT Center in India and Sahelian Center in Niger; red dots indicate collaborative research stations with resident ICRISAT staff.

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 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 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

In a year when drought was devastating in so much of the world, ICRISAT made progress against it. Lines of our five mandate crops outyielded local cultivars in widespread tests across drought-prone areas of the semi-arid tropics (SAT). In some cases where drought was severe, test lines doubled or tripled the yields of standard varieties.

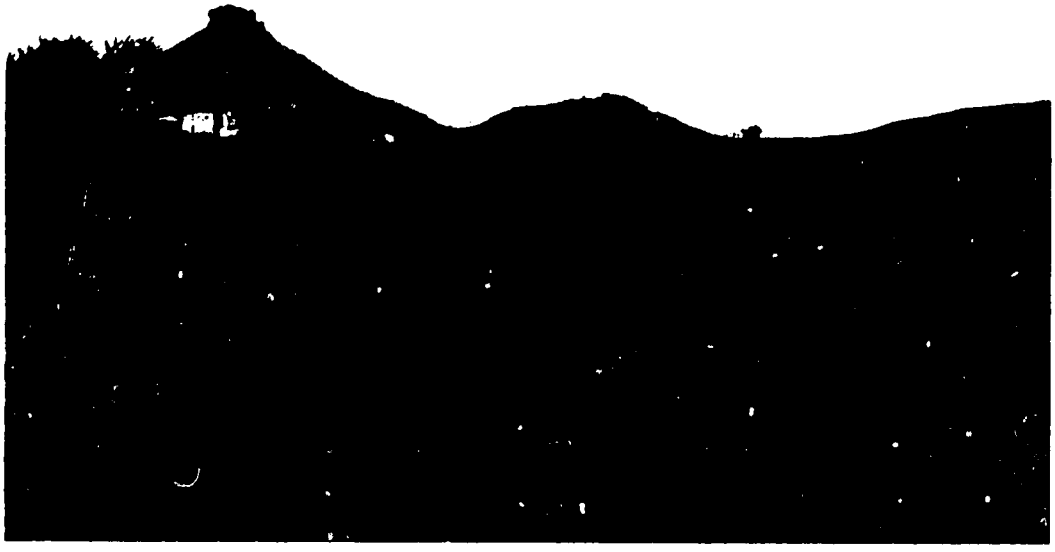
We are screening for drought resistance in the dry season at Anantapur in southern India, where drought occurs 1 year in every 3, and we are constructing rain-shelter facilities at ICRISAT Center so that we can test for drought during the normal rainy season as well. We will coordinate drought research with our Sahelian Center in Africa, as well as with national scientists in Asia and other drought-prone areas of the semi-arid tropics. Learning how to cope with drought has a high priority in our future work.

We also made progress this year in controlling the other major yield reducers of our mandate crops: diseases and pests. We are developing breeding lines that are resistant not just to one but to several diseases, and some to insect damage as well. These are being turned over to breeders in national programs throughout the SAT for use in producing locally adapted varieties.

In India, we were gratified to see a substantial increase this year in the area under verification of our technology for double cropping deep black soils, which can add enormously to the country's food production. In Africa, we moved forward in developing an interdisciplinary team and research facilities at the ICRISAT Sahelian Center in Niger, establishing a base in one of the most chronically drought-prone areas of the world. The major work there is on pearl millet, a staple food of the region, and with our sister institutes IITA and ILCA on cowpeas and livestock in farming systems of the region.

Our pearl millets are improving yields for farmers in India and in some areas of West Africa, and our sorghums have been released to farmers in seven countries of the SAT and are nearing release in seven others, including India and China. In 1984 we will launch a major regional improvement program for both of these staple food crops in the drought-prone countries of the Southern African Development Coordination Conference (SADCC).

An ICRISAT groundnut variety that has yielded up to 7000 kg per hectare under research-station conditions is now in minikit trials on farmers' fields in India for irrigated dry-season cultivation. We have also developed high-yielding lines with resistance to foliar diseases for use in the rainy season when diseases are a problem.



Testing of selected groundnut cultivars under rainfed conditions at Anantapur, southern India.

An ICRISAT chickpea variety was released to farmers in Gujarat, India, and an early-maturing pigeonpea produced 5500 kg/ha from three harvests, compared with the 2500 to 3000 kg/ha that pigeonpea normally yields in India from two harvests.

We feel that ICRISAT is well on the way to meeting its mandate to increase food production in the semi-arid tropics of the world. Our progress toward that goal is reported briefly on the following pages and in more detail in the 1983 ICRISAT Annual Report.

L.D. Swindale
Director General

Making Progress Against Drought

Drought and associated stress factors are a constant threat to crops in the semi-arid tropics. Several factors account for such stresses—extreme heat, sandstorms, marginal soils, highly variable rainfall.

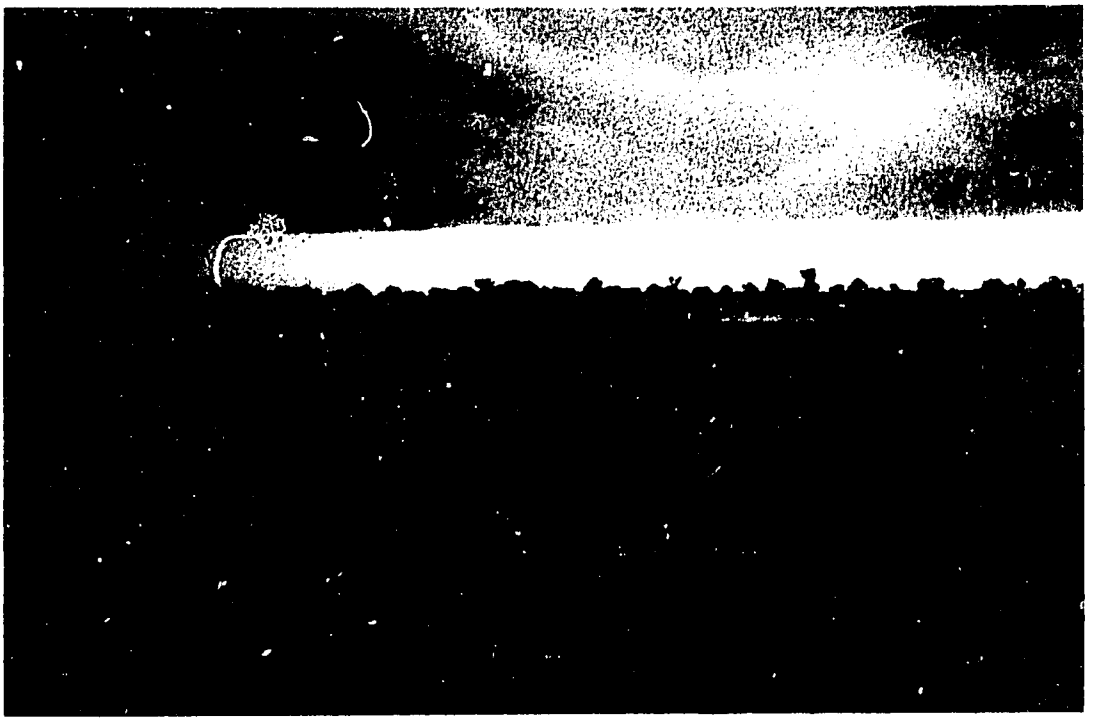
Identifying crop varieties that can grow well under such sudden and extreme stresses has a high priority in ICRISAT's research. Farming systems and improved practices that adapt to those conditions also help farmers cope with bad situations.

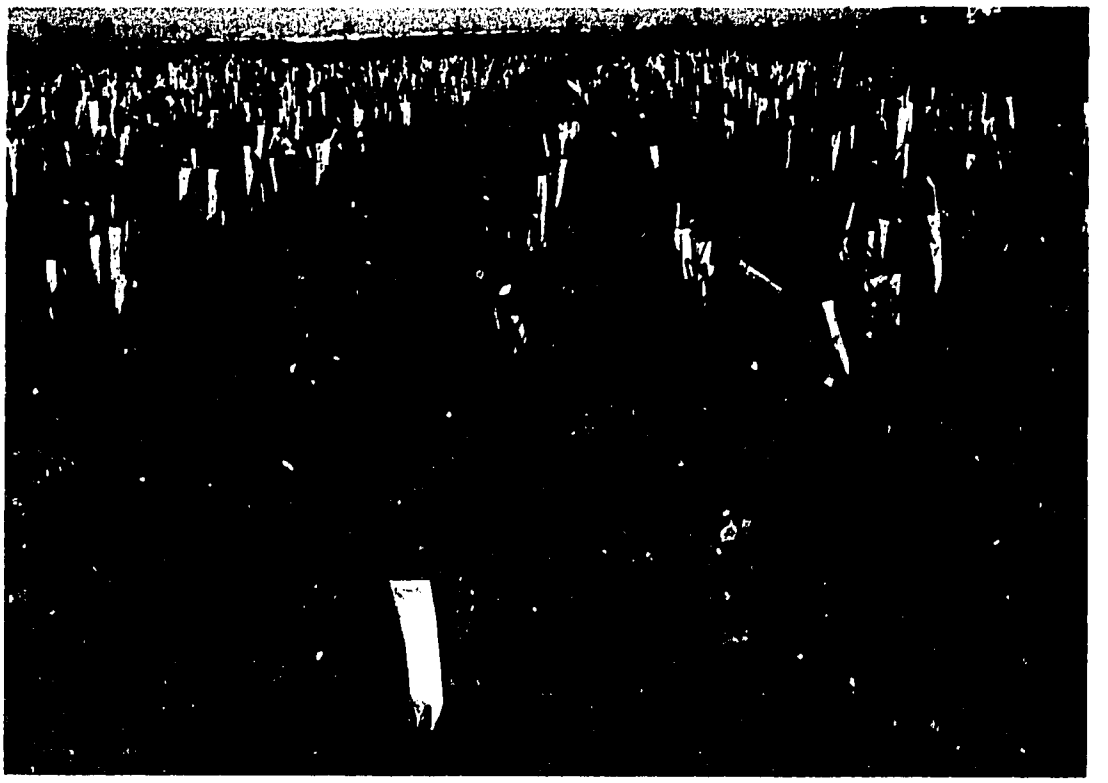
ICRISAT's 1983 progress in drought resistance was reassuring at a time when many SAT countries were hit by one of history's worst droughts. Important advances were made in screening and breeding for drought resistance and in evolving suitable cultural practices.

Under severe drought at Anantapur, in southern India, six ICRISAT sorghum lines yielded two or three times as much as the best local cultivars. At the same location, with only 220 mm (9 inches) of rain during the crop life, groundnut NC Ac 17090 produced 2530 kg/ha, compared with 1100 kg/ha by Robut 33-1, the recommended cultivar.

At Maradi, Niger, with only 222 mm of rain, pearl millet ITMV 8002 yielded 20% more and ITMV 8004 14% more than the standard cultivar, CIVT. Both lines also yielded well in Cameroon, Nigeria, and Sudan in multiloca-

A sandstorm at the ICRISAT Sahelian Center, Niger, indicating the stresses that growing crops must endure in the semi-arid tropics.





Pearl millet ICMS 7703 being reselected for drought tolerance at ICRISAT Center. Two Indian states already are producing seeds of that variety.

tional trials for areas that receive less than 400 mm (16 inches) of rainfall a year, as well as in areas where rainfall exceeds 400 mm.

In the dry Sudan region, where farmers' traditional cultivars failed, two ICRISAT sorghum lines produced more than 4000 kg/ha each.

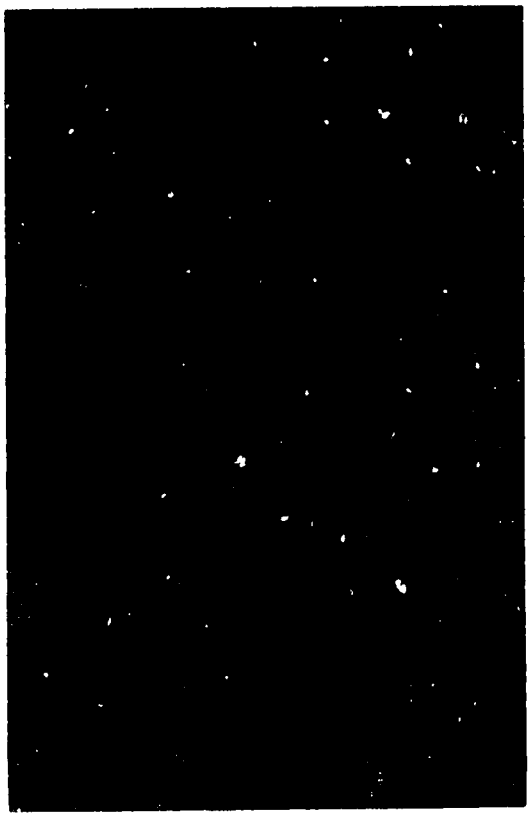
Three sorghum germplasm lines that originated in different countries, Botswana (IS 22314), India (DJ 1195), and Sudan (IS 22380), were drought resistant at both ICRISAT Center and Anantapur, and when planted at different dates.

Planting dates were important in escaping drought. Either early- or medium-maturing lines were best, and late-maturing lines produced tall forage with low grain yields.

The Indian states of Andhra Pradesh and Tamil Nadu have state agencies producing seed of ICRISAT pearl millet ICMS 7703, which performed well in drought tests. The National Seed Corporation plans to supply seeds of this millet to all major millet-growing areas of India. It is expected to be released to farmers in 1984.

We have found tolerance in groundnuts to midseason and end-of-season droughts, the common SAT drought periods. Groundnuts are less affected by drought in their early plant life. This year we found that seeds from groundnuts grown under moisture deficits from emergence to peg initiation produced larger seed and higher germination rates, pod yield, and shelling percentage.

Our early-maturing, drought-tolerant chickpea genotype, ICC 10448, produced 2050 kg/ha of seed on nonirrigated black soils and 800 kg/ha in the drought environ-



ICRISAT groundnut lines (center) performed well in a drought trial where other lines were destroyed.

ment on red soils, compared with 200 to 400 kg/ha by the susceptible entries.

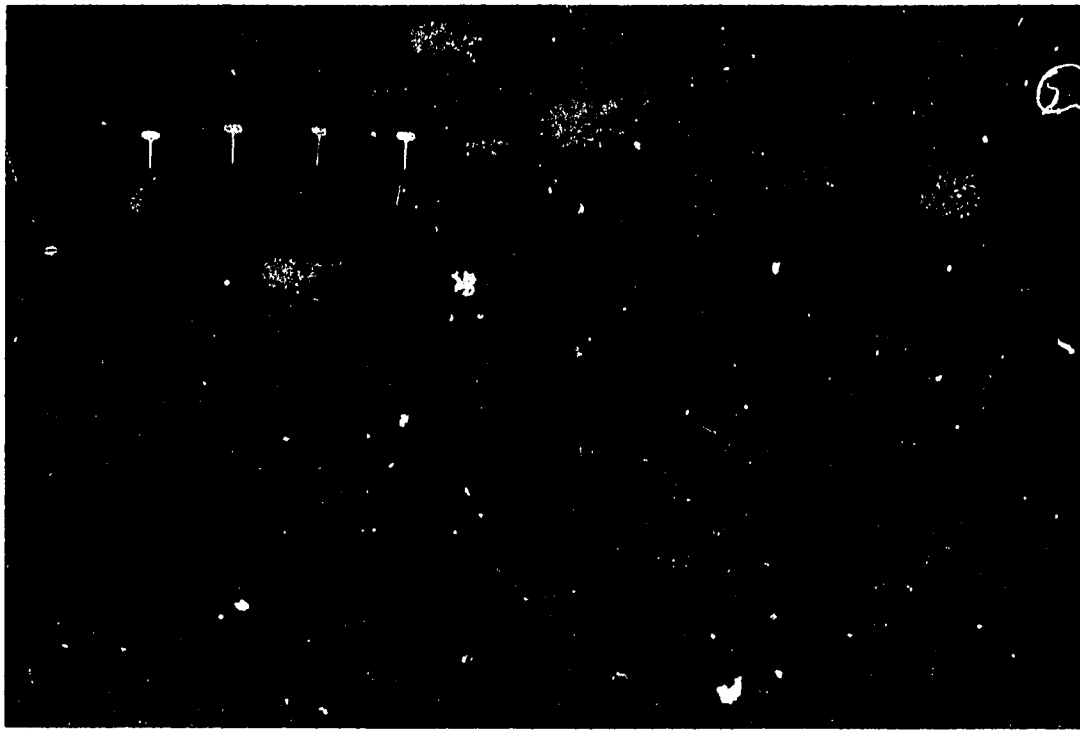
We think early maturity is equally important in Africa. Mali's meteorological services and ICRISAT have updated rainfall, temperature, and evapotranspiration data to predict chances for given amounts of rain. Such work should help national programs fit crop maturity to rain and permit the use of drought escape in developing new varieties and hybrids.

We also have calculated expected rainfall at different probabilities for 58 locations in Upper Volta. ICRISAT scientists are using the information in research in four Upper Volta villages.

In cropping systems research in Africa, the newly introduced, early-maturing sorghums did well alone, or intercropped. While drought destroyed late-maturing sorghum, early-maturing material intercropped with millet, cowpea, or groundnut yielded from 700 to 1500 kg/ha.

The technique we developed to select lines that will emerge through dry soil with

Testing of chickpeas at ICRISAT Center for drought conditions. Moisture deficits are created and daylengths extended by using lamps.



Differences in ability to emerge through crusted soil are assessed in sorghum genotypes. Seedling vigor to break through soil crusts is valuable in drought environments.

high surface temperatures is being used by national scientists in Mali, Niger, and Senegal.

Testing advanced sorghum and millet breeding lines and germplasm with soil temperatures up to 50°C as deep as 20 mm showed wide differences in ability to emerge. The most promising material will be used in ICRISAT breeding programs.

Last year we developed a crust breaker to improve plant emergence. This year, using an improved technique to screen sorghum genotypes for ability to emerge through crusted soil, we found that all the seedlings of IS 2877, a germplasm accession that originated in Egypt, emerged, compared with no seedling of more than half the entries in the test.

Seedling vigor to break soil crusts is a valuable characteristic in the drought environments of SAT countries.

These findings are critically important to future research on how to help farmers cope with this natural, continuing barrier to agricultural development in the SAT. We now need the ability to predict droughts, because early-maturing crop lines are susceptible in a normal year to molds, rots, and pests. West African landraces avoided those problems by maturing late.

Developing and Combining Resistance

All ICRISAT crop improvement programs aim to develop high-yielding and stable varieties and hybrids with acceptable food quality. But stability of yield depends upon adaptation and resistance to numerous factors that reduce yield—insect pests, diseases, weeds, and drought.

Even as they try to develop elite varieties or hybrids with good yields, ICRISAT scientists are busy identifying and strengthening sources of resistance to the various yield-reducing factors. A further process is to select for and incorporate several traits simultaneously into lines that can do well agronomically.

Materials so tested and developed are given to scientists in national programs for further evaluation and use. National scientists provide us, in return, valuable information on crop performance in relation to specific yield-reducing factors in their countries. So while ICRISAT's work moves forward, national research capability is also fortified to the advantage of farmers in poorer

Ergot resistance trials at ICRISAT Center. Twenty pearl millet lines have been identified with combined resistance to all three major diseases—downy mildew, ergot, and rust.

countries.

ICRISAT has become a major source of materials with high resistance to specific diseases of pearl millet, as well as with multiple resistance. All sources of resistance to ergot, smut, and rust, which we have identified or developed, have resistance to downy mildew because all are screened in our downy mildew nursery.

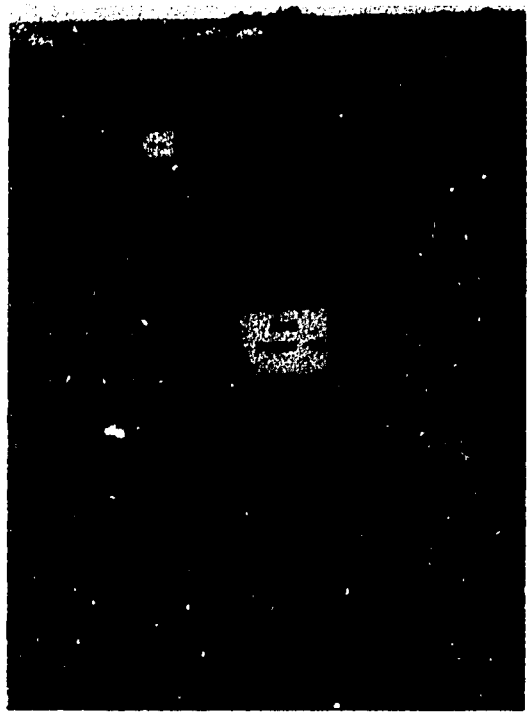
Twenty lines with resistance to all three major pearl millet diseases—downy mildew, ergot, and smut—have been identified at ICRISAT Center, and half of them have already performed well agronomically in multilocational tests in India.

The three most serious diseases of groundnut worldwide are rust, early leaf spot, and late leaf spot. Each of them can reduce yields 50%; when they occur together, losses are worse. We have no breeding line yet with resistance to all three, but we have eight lines with high resistance to rust and late leaf spot. Breeding lines with such resistance are being widely tested in Asia and parts of Africa. In India they significantly outyielded recommended, susceptible cultivars. Three ICRISAT lines yielded more than 3000 kg/ha in 1983 rainy-season trials in low fertility, rainfed, unprotected conditions. And we have identified three lines with resistance to rust and early leaf spot.

Our success in breeding for multiple disease resistance in chickpeas is impressive. We now have 18 lines resistant to wilt and black root rot; 17 to wilt and dry root rot; 2 to wilt, dry root rot, and black rot; and several more that resist two—wilts, molds, or blights.

In 1983 tests alone, eight lines resisted fusarium wilt and dry root rot; one, wilt and botrytis gray mold; one, wilt and ascochyta blight; one, botrytis gray mold and ascochyta blight; and one, stunt and ascochyta blight. Fifty germplasm accessions came through the 1982/83 multiple disease-sick plots with less than 10% mortality to wilt and root rots.

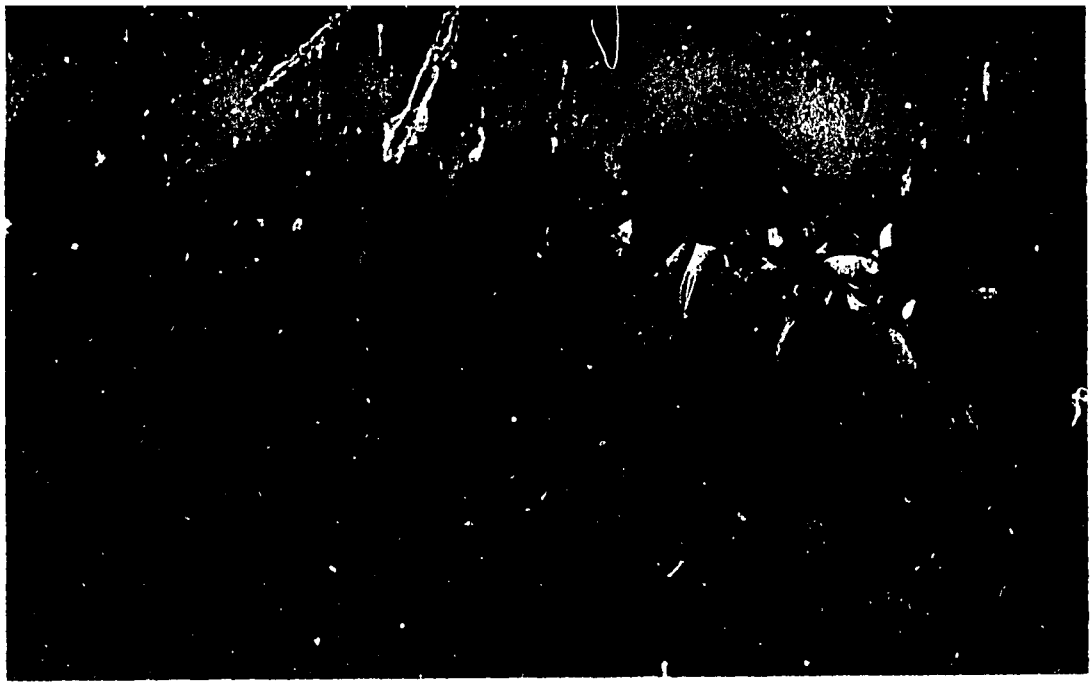
The three major diseases of pigeonpea are wilt, sterility mosaic, and phytophthora blight. In screening and breeding for combined resistance to all three, we identified 11 progenies that were free from infection by all three diseases and 53 progenies with less than 20% of any disease.



The ICRISAT groundnut line in foreground is resistant to rust and late leaf spot. Two standard cultivars (at back) are susceptible.

A pigeonpea line resistant to phytophthora blight, ICPL 161, yielded up to 3200 kg/ha in multilocational trials. Two of 28 lines from a cross to transfer *Heliothis* resistance performed far better than the standard control under heavy insect attack.

Several medium-maturity lines that resist wilt and sterility mosaic outyielded the standard control under disease-free conditions. We already have early-maturing lines resistant to both diseases.



A wilt-resistant pigeonpea line (left) besides a susceptible one. ICRISAT scientists have identified so far more than 50 lines that resist wilt.

Differences in resistance to shoot fly. Of 83 sorghum lines identified for that trait this year, 10 had good yields, and 4 of them had multiple resistance to other pests and diseases.

Over 3 years of testing, we identified 24 progenies that resist sterility mosaic disease from 14 lines with resistance to *Heliothis* and podfly.

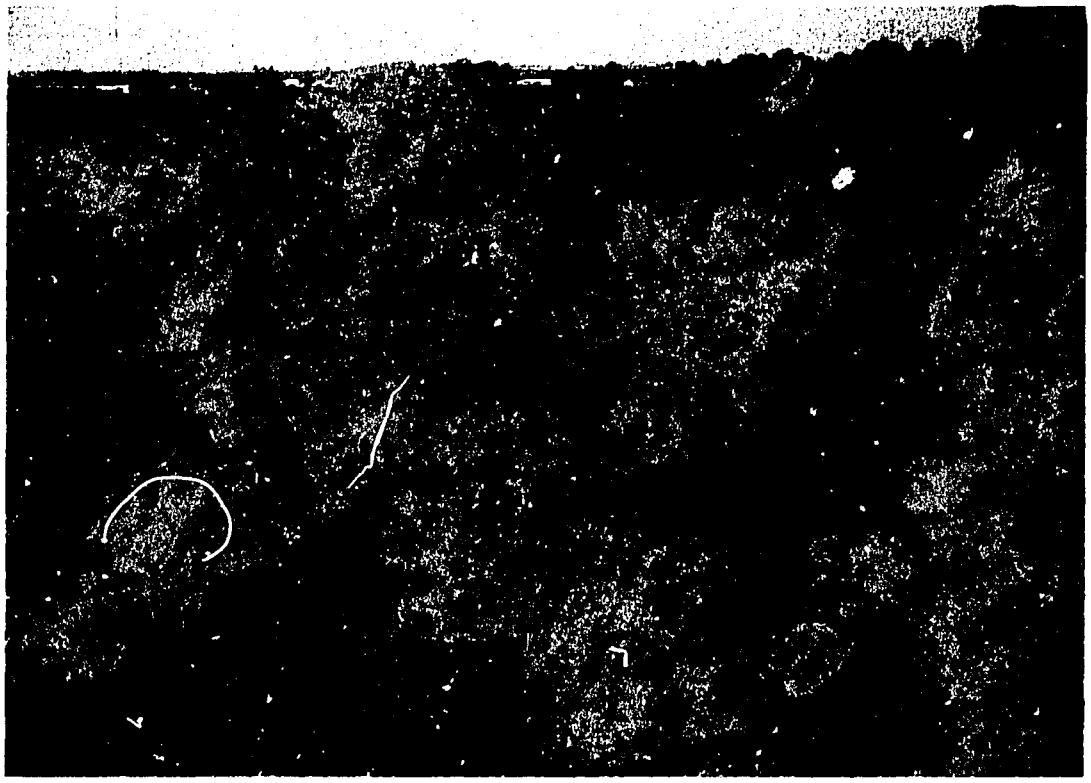
Of 83 sorghum lines identified for shoot fly resistance in 1983 tests, 10 had excellent yields (60% or more above the susceptible variety) and 4 of them had multiple resistance. One line had resistance to rust, anthracnose, downy mildew, and shoot bugs; another to downy mildew, leaf rust, and shoot bugs; a third to rust, anthracnose, and shoot bugs; and a fourth to anthracnose and downy mildew.

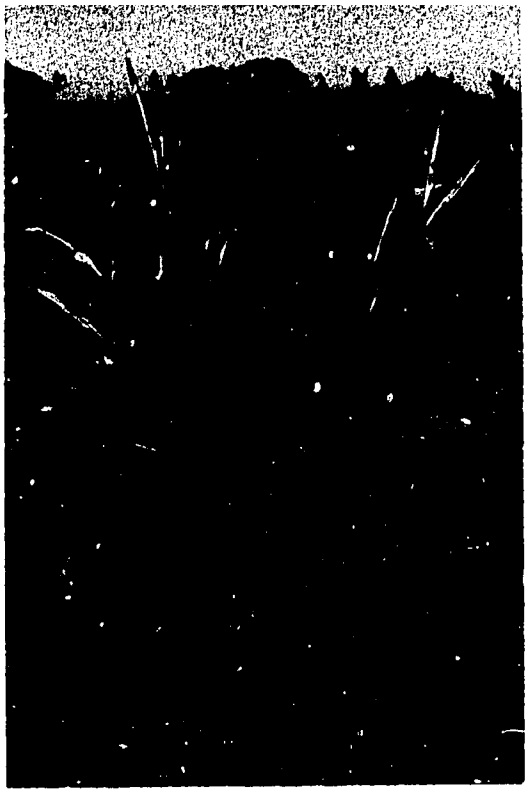
Viruses can seriously damage groundnuts, but most are limited to specific areas. Only peanut mottle virus disease occurs to any great extent globally. We identified during 1983 two groundnut genotypes that showed zero seed transmission of peanut mottle virus and another that is tolerant of the disease.

Even though new material for Africa must withstand stronger attacks by insects and diseases and harsher heat and drought, 38 pearl millet selections from Senegal, Upper Volta, and India also had multiple resistance to downy mildew, ergot, and smut in 1983 tests in Nigeria's diseased plots. Of the 252 base parental lines tested there, 98 resisted all three diseases.

Ascochyta blight, a major destroyer of chickpea crops, has been epidemic in many of the 25 countries where it occurs in Africa, Asia, Europe, the Americas, and Australia. The ICRISAT pathologist based at ICARDA, Syria, concentrates on it, and the variety released in Syria, ILC 482, resists the blight.

Ascochyta blight resistance: ILC 3279, developed by ICARDA/ICRISAT, resists the disease (center) while other tested lines are killed.





Downy mildew in sorghum: in tests this year, 12 lines with high resistance were identified, some of them with high yields and good agronomic backgrounds.

Eleven national programs already are using in their breeding programs sources of resistance to ascochyta blight identified by us.

Screening techniques developed by ICARDA/ICRISAT are now being routinely used against wilt, root rots, stunt, and ascochyta blight in Ethiopia, India, Nepal, Pakistan, Syria, and Tunisia.

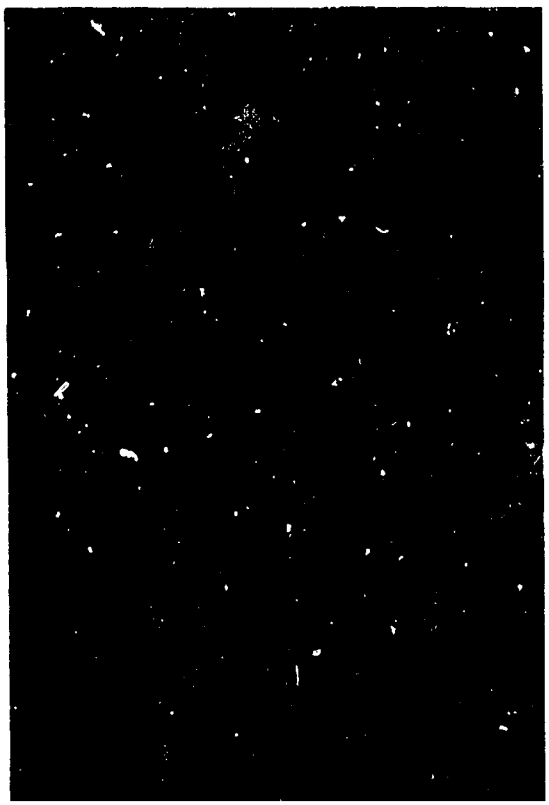
Two of 27 sorghum entries tested this year were resistant to grain mold at all eight locations where mold development was expected—in Brazil, Mexico, Philippines, Thailand, Upper Volta, and three in India. Seven others resisted the mold at seven of the eight locations.

We identified 12 sorghum lines with high resistance to downy mildew, some in good agronomic backgrounds.

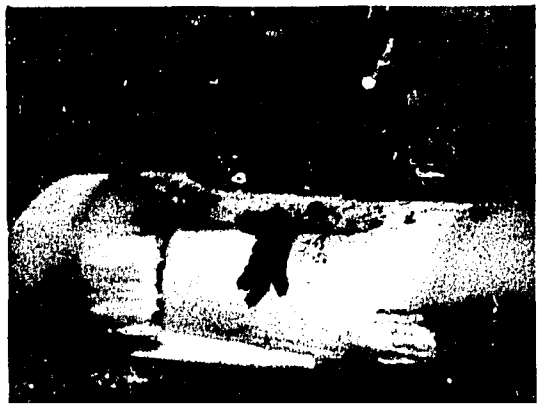
The stem borer rearing facility was improved to speed work on resistance to that insect pest.

We made particularly good progress with pigeonpeas that resist wilt. In multilocational trials in India, we identified two lines that were resistant at 9 of 11 locations. In Kenya we identified 7 wilt-free lines and in Malawi 10 lines free of both wilt and root knot.

We also have 21 wilt-resistant lines identified in 3 years of testing in wilt-sick plots. Three of the eight early-maturing lines that had less than 20% wilt in 1981/82 showed below 10% wilt this year.



At left, stem borer damage in sorghum; below, the insect at work. ICRISAT has improved its stem borer rearing facility to speed work on resistance to this insect pest.



Genotypes that resist foliar diseases in groundnuts are used as parents in breeding programs. High-yielding lines with good agronomic traits have been developed from crosses between cultivated groundnuts and wild species. Likewise, groundnut genotypes with multiple insect-pest resistance have been used in breeding, and some progenies tested this year showed good resistance and high yield potential.

Aflatoxin still remains a serious problem. Although we have lines that resist seed invasion by the fungus, this resistance is lost if the seed coat is damaged. Satisfactory control will occur only with an integrated approach of resistance, correct harvesting, and drying.

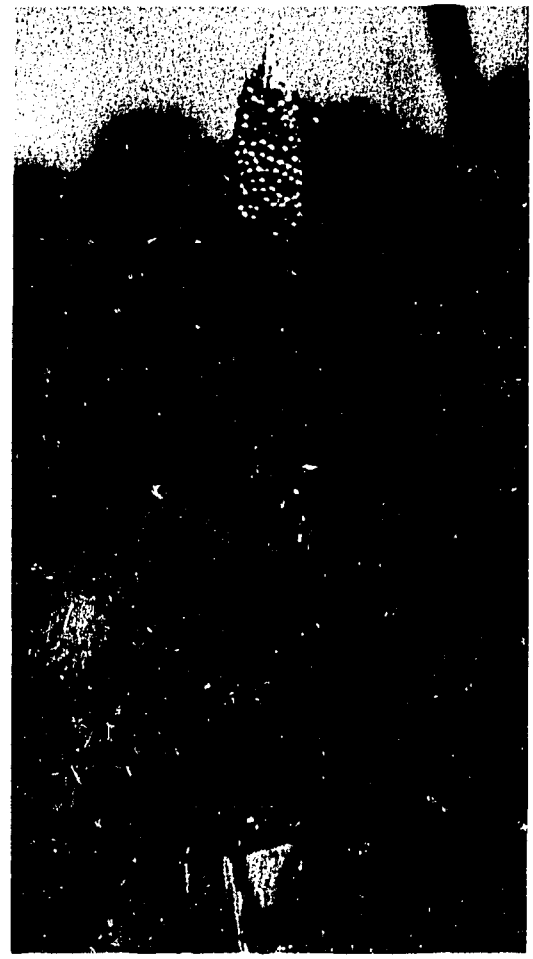
Smut-resistant sources of pearl millet from ICRISAT Center are being used in our breeding programs in Senegal and at the ICRISAT Sahelian Center (Niger), where smut is extremely severe. Seed samples of rust-resistant sources have gone to Kenya, Malawi, Uganda, and Zambia.

Pod and root damage caused by fungi and nematodes can also greatly reduce groundnut yields. Along with scientists from the Andhra Pradesh Agricultural University, we investigated a new disease of groundnut pods causing yield reductions in Andhra Pradesh, identified the causal nematode, and recommended control measures. We also identified resistance to pod-scarifying termites in 10 genotypes.

Over the years our scientists have identified or developed more than 600 sorghum lines with one useful resistance or another. We are now combining several traits in lines that can grow well on farmers' fields.

Several agronomically good sorghum lines that resist midge became available this year. We also identified some new mechanisms of resistance to shoot fly, by artificially rearing shoot flies and infesting sorghum lines with them.

Efforts are under way to involve physiologists and pathologists jointly in work on root and stalk rot diseases, based on the recommendations of a workshop ICRISAT held with INTSORMIL (the USA sorghum and millet improvement program) in November 1983 at Bellagio, Italy.



Smut is a severe problem in pearl millet at the ICRISAT Sahelian Center. And smut-resistant sources are now in use.

Progress has thus been made in all our crop improvement programs to identify sources of resistance and to develop them in breeding lines or cultivars. That work will continue, and we will focus our efforts on combining multiple resistance traits in varieties that can grow well on farmers' fields.

On-Farm Verification of Black Soil Technology

The technology developed by ICRISAT for double cropping deep black soils with assured rainfall (750-1250 mm per year) continued to do well in 1983 on-farm verification in India. Testing of this technology was extended by state departments of agriculture to 22 locations from 8 the previous year in the four Indian states—Andhra Pradesh, Karnataka, Madhya Pradesh, and Maharashtra—where we work in cooperation with them.

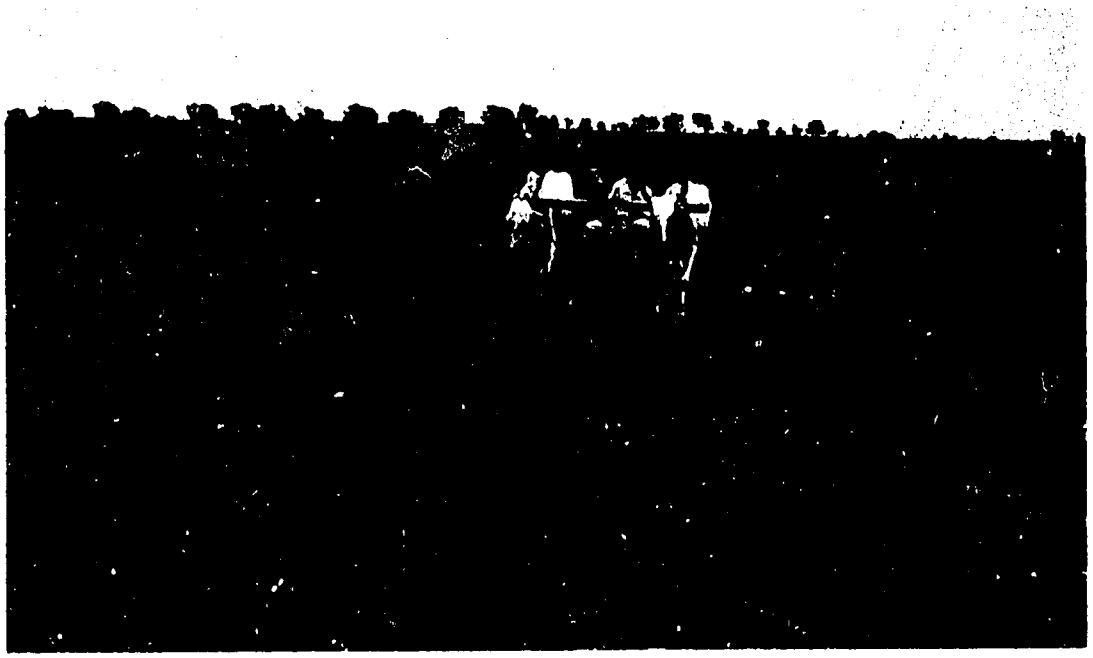
Based on a watershed approach, the technology seeks to make maximum use of available land and water resources to improve crop production. A watershed is the land area from which rain or applied surface water drains to a single outlet.

During 1983 tests, returns on additional investment arising from the improved technology ranged from 26% to 381% across locations. Land development costs varied from Rs 200 to 1000 per hectare, but the high of Rs 1000 (US $100) was still much cheaper than the cost of providing irrigation.

Based on results on farmers' fields in Karnataka, the state government decided to expand the area under testing, and has set up a dryland development authority to oversee watershed-based development.

The on-farm tests also improved our grasp of problems farmers faced. Ineffective control of *Heliothis* by farmers reduced their potential profits by as much as Rs 2500 per hectare. Managing weeds continued to pose

Land preparation in progress at Farhatabad village, Karnataka.



difficulties as interculture with the wheeled tool carrier only partly succeeded in removing weeds, so more research is needed. The wheeled tool carrier and its attachments are too expensive for most farmers, so costs need to be lowered. The locally manufactured models have not always met the required standard of precision in operations, so better quality control is needed.

In addition to tests of the technology on farmers' fields, trials were undertaken on two cooperating experimental stations in Madhya Pradesh to provide an intermediary step that would link ICRISAT knowhow to conditions in which it would need to be used. The trials covered both cropping systems and land and water management practices.

The tests will continue, so that we can provide for variations in rainfall across years in planning crop production, and can better understand how crops perform or why farmers select the crops they grow. Such knowledge helps tap the full potential of each region for crop production.

Training is an important need in on-farm testing. Our experience with on-farm tests indicates that poor results may stem from improper or incomplete application of technology. Often, simple remedies or timely practices may save a crop or improve yields if the knowledge is available on the spot.

Cooperating farmer in on-farm verification at Farhatabad gets a tip from extension official of the Karnataka government.

Farmer and grandson view a pheromone trap installed at Begumganj, Madhya Pradesh.

Training becomes doubly important when more area is brought under new technology, as is happening. Extension personnel working in areas with deep black soils at or near test sites were provided 380 man days of training at ICRISAT Center, in addition to seminars held by visiting ICRISAT specialists at specific locations.

Financing is another key area in the introduction of technology. When farmers test a new set of practices, they often need to find loans for the added investment, a problem that is most acute for subsistence farmers. ICRISAT hosted a workshop in October 1983 to address the problem of financing dryland agriculture. Bankers and financial administrators took a major role in the discussions, perhaps for the first time. The workshop was cosponsored by India's National Bank for Agriculture and Rural Development and the Indian Council of Agricultural Research.

Augmenting Genetic Resources

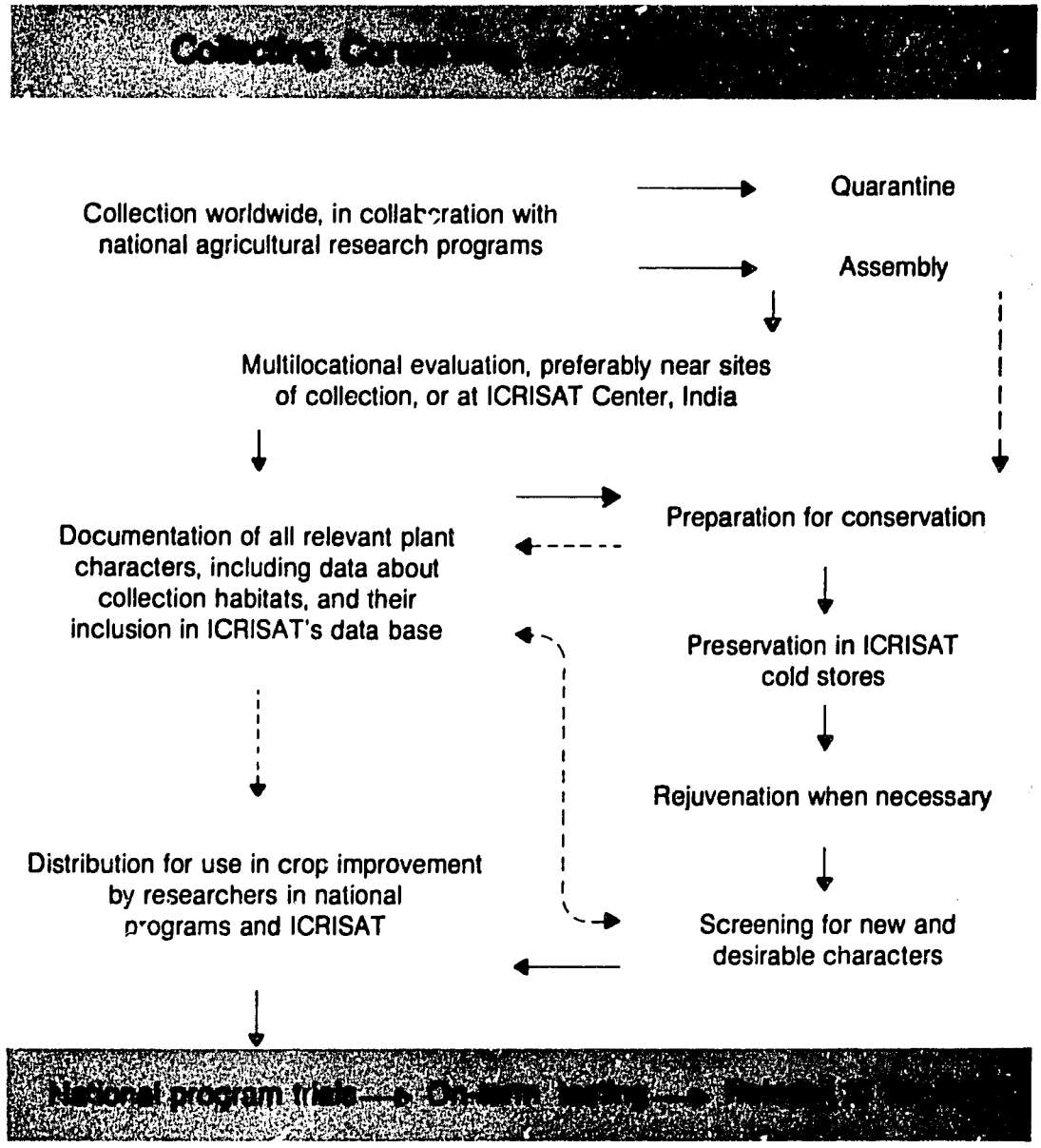
Until now crop improvement scientists have been fortunate in finding in farmers' fields germplasm lines necessary for evolving new varieties. But the situation is changing. Ecological pressures are forcing many plants out of their natural habitat, causing serious genetic erosion to such an extent that man-made gene banks may become the only source of germplasm.

Important germplasm collections were added at ICRISAT Center during 1983 from Cameroon, Malawi, Nigeria, Sierra Leone, Sudan, and parts of India not previously represented. Many countries and parts of countries, where our mandate crops are important, remain unrepresented. Collecting from them will require help from governments and cooperating scientists in arranging for collecting expeditions in areas not now accessible.

At the end of 1983, germplasm collections at ICRISAT Center exceeded 76 000. Distributions during the year also exceeded 76 000:21 000 samples of sorghum to 29 countries; 11 000 of chickpea to 14 countries; 3000 of groundnut to 21 countries; 2000 of pigeonpea to 17 countries; 1000 of pearl millet to 16 countries; 1000 of minor millets to 10 countries; and 38 000 of all mandate crops to ICRISAT scientists.

Farm family in Sierra Leone displays some sorghum landraces.

Clockwise (from top left): Pigeonpea collection in Malawi, collecting sorghum germplasm from Sierra Leone; evaluating pearl millet in Upper Volta; and a three-podded chickpea mutant identified at ICRISAT Center. Efforts in genetic resources will now be focused on areas that remain unrepresented in ICRISAT's gene bank.



Surveying 200 scientists to whom we sent seeds, we found that some 200 germplasm lines across all five ICRISAT crops already have been used for improving yields, developing disease or insect pest resistance, or in trials of promising lines.

We are devoting attention to assembling and conserving wild species, of particular benefit in improving crops. ICRISAT is committed to supplying clean, viable, and useful seeds to scientists who need them. Our collection is shared freely with all who request it.

Sorghum Advances

ICRISAT sorghum varieties and hybrids are growing on farmers' fields in seven countries of the SAT and are nearing release, or in advanced stages of testing, in seven other countries.

New high-yielding, disease-resistant lines were released to farmers this year in Upper Volta, Sudan, Zambia, Mexico, and Venezuela, following earlier releases in Ethiopia, Upper Volta, and El Salvador.

In India, where up to 7 years of national testing is required before release to farmers, the first ICRISAT sorghum variety, ICSV 1, is likely to be released in 1984. In 4 years of testing in the All India Coordinated Trials as breeding line sorghum project variety (SPV) 351, it yielded as well as the popular commercial hybrid CSH 1 (3490 vs 3290 kg/ha). In minikit trials on farmers' fields at several hundred locations in India, it yielded 1240 kg/ha on average against 740 kg/ha for the local cultivar. ICSV 1 has good grain quality, resistance to some leaf diseases, and it produces well under low fertility.

Cold-tolerant sorghum hybrids being developed for the highlands of Mexico and Central America. ICRISAT varieties already are growing in El Salvador, Mexico, and Venezuela.

Ten other ICRISAT sorghums are also in the pipeline of the all-India testing system, three of them in the prerelease stage just behind ICSV 1, and they should add substantially to India's sorghum production.

In China, four ICRISAT sorghum lines are in advanced yield trials as Yuan 1-54, Yuan 1-98, Yuan 1-28, and Yuan 1-505.

In the Yemen Arab Republic, ICRISAT variety SPV 476 is being considered for release and another line, M-36131, is giving consistent high yields in the Tihania area of the country.

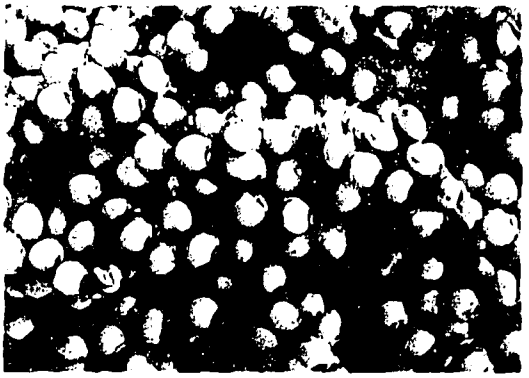
In Guatemala, seeds of several ICRISAT varieties have been increased for extensive on-farm testing, and in Nicaragua, seed of ICRISAT variety SEPON-8-1 (PR-113-114) has been increased for wide-scale testing.

A variety released to farmers in Upper Volta this year is Framida, a South African sorghum introduced through the ICRISAT program based in Kamboinse. It is high yielding and resistant to *Striga hermonthica*, the parasitic weed that destroys sorghums in much of Africa.

In Togo this year, Framida yielded 10 times more than the local *Striga*-susceptible varieties. Its yields were 40% superior to local varieties in each of 7 years (1977-83) in nine African countries and averaged 1270 to 910 kg/ha for that period. It has yielded well in our tests and in preextension trials in Upper Volta. We are also testing other varieties with resistance to *Striga* in Ghana, Sudan, and Togo.

ICRISAT's Striga*-resistant sorghum, SAR 1, on a farmer's field in Maharashtra, India.*

A white-grained sorghum. Improving food-type sorghums is an ongoing part of ICRISAT's work.



Good progress was also made this year in India against *Striga asiatica*, the form that occurs in Asia. Fourteen of our lines with moderately good yield and high resistance to *Striga* are in national screening nurseries in India. One of them, SAR 1, has advanced to on-farm testing in three states, and another, SAR 2, in one of those states.

Resistance to insect pests and diseases will be incorporated into *Striga*-resistant lines to improve their yield stability.

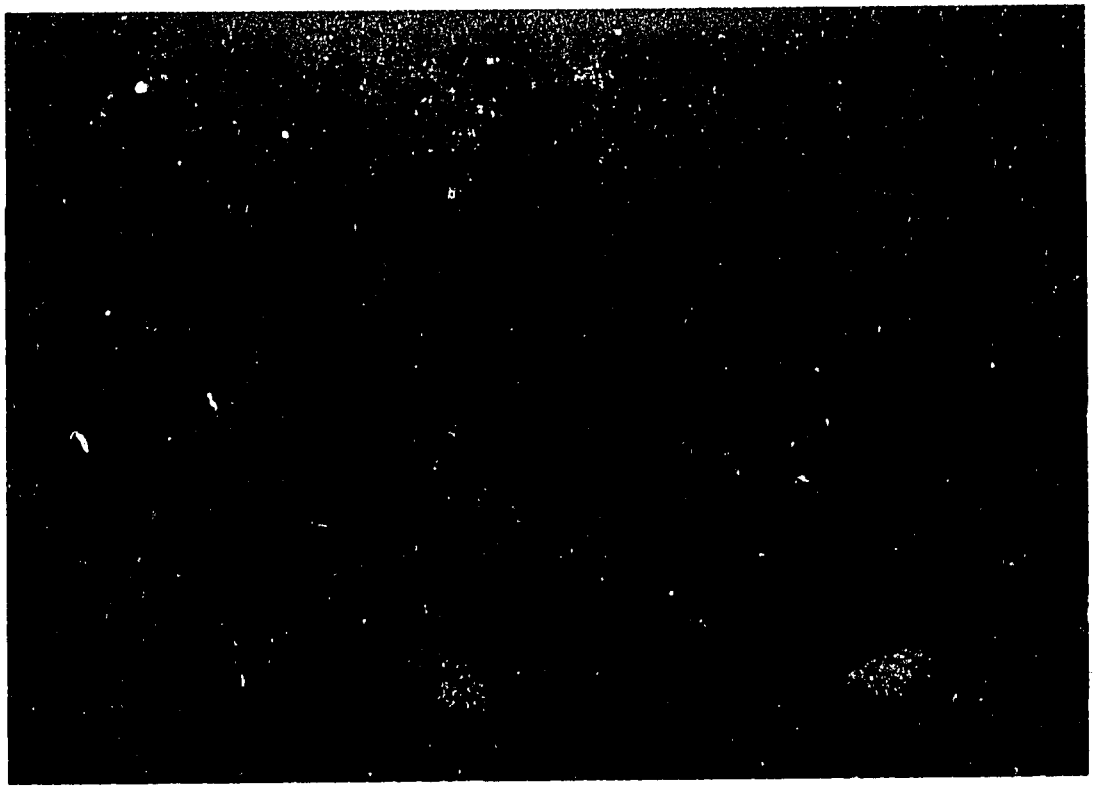
Pearl Millet Advances

ICRISAT's first pearl millet variety to reach farmers in India is winning rapid acceptance. ICMV 1, tested for 7 years in the all-India trials as WC-C75, was released to farmers last year. This year it is being grown on 240000 hectares, and 18 seed producing agencies in nine states have taken 390 kg of breeders' seed for multiplication. They predict that next year there will be enough seed to plant 600 000 hectares.

ICMV 1 is high yielding and resistant to downy mildew, which devastates pearl millet and was the primary reason we focused on breeding for resistance to this disease in ICRISAT's early years. It arrived in the hands of farmers at an opportune time: the popular Indian hybrid BJ 104, which yielded approximately the same as ICMV 1 in the all-India tests, has been losing its resistance to downy mildew.

Using the parents of BJ 104, which are in our gene bank, ICRISAT scientists this year developed a fast-restoring technique to replace the resistance it had lost. But ICMV 1 may supersede it, because it is a variety with assured resistance, and farmers can grow their own seed. It responds well to applied fertilizer, but does not require it.

ICRISAT pearl millet ICMV 1, earlier known as WC-C75, growing on a farmer's field in Andhra Pradesh, India. It covered nearly a quarter million hectares in India this year.



Making better hybrids: ICRISAT's developing of disease-resistant male-sterile lines has improved prospects for hybrids with more stable yields.

A second ICRISAT millet, ICMS 7703, is nearing release in India and should do as well or better than ICMV 1. In 5 years of all-India testing it yielded an average 1930 kg/ha, 3% more than WC-C75 did in the same trials. It also has resistance to downy mildew and ergot and has performed well under drought conditions.

Two ICRISAT millets bred in Senegal performed well this year in the West Africa regional trials of the Institut du Sahel (INSAH). IPV 8004 was first in those trials with 16.7% more yield than the control, Souna III, and IPV 8001 gave 11% more. Two of our synthetics, ICMV 2 and 3, have outyielded Souna III by 22% over 3 years in Senegal and are in the prerelease stage there. Sudan has released an ICRISAT millet under the name Ugandi.

Our successful recurrent selection program at ICRISAT Center has boosted yields 2 to 7.6% per cycle or 1 to 3% a year with no letup indicated. New varieties being tested now are yielding 10 to 15% more than WC-C75 (ICMV 1). The increases came from six high-yielding composites selected from 2 to 5 cycles over the last 3 to 8 years. Our breeders carefully included in each recurrent composite a range of West African parents from areas where downy mildew and other major diseases are endemic. This may have an important future impact in Africa, where drought will remain a problem. Millet resists drought better than any other ICRISAT crop.

ICRISAT is the only source of materials with high resistance to ergot, a major disease of pearl millet, and has become the principal source of new male-sterile millet

lines for breeding programs worldwide. The development, on male-sterile lines, of new material resistant to downy mildew and ergot makes prospects excellent for newer, higher-yielding hybrids.

Kansas State University, USA, and ICRISAT developed this year two early, downy mildew resistant seed parent lines that will enable breeders in India to make new hybrids in their own localities. These and three others have been distributed through India's national millet improvement program; newly developed hybrids based on them will be tested in 1984.

Groundnut Advances

A promise of improved yields in groundnuts (peanuts) is important in the semi-arid tropics for several reasons: 70% of the world's groundnuts are produced in the SAT; they are rich in edible oil, which is scarce in SAT countries; they are high in protein (about 25%); and they are an important cash crop for SAT farmers as well as a nutritious food.

Breeding of groundnuts for improved yields and multiple pest and disease resistance at ICRISAT Center.

Rosette virus is a groundnut disease specific to Africa. ICRISAT's regional groundnut program in Malawi works on problems of that area.

For these reasons, extraordinary yields from ICRISAT's 1983 trials with groundnuts may signal an important future contribution to countries in Asia and Africa and other areas where groundnuts can improve diets, incomes, and trade balances.

Groundnut yields in the SAT average 800 kg per hectare. In research-station conditions, we had three lines in 1983 that exceeded yields of 7000 kg/ha, and another that yielded 6620 kg/ha.

The ICRISAT selection ICGS 11, developed for postrainy-season, irrigated conditions, was promoted to minikit trials on farmers' fields in the central and peninsular zones of India. Three other selections are in India's national evaluation trials.

All the material from ICRISAT trials is available for our groundnut breeder and pathologist at Chitedze Research Station, Lilongwe, Malawi. Their work with groundnuts is important in southern and eastern Africa. Although the team started work there only in September 1982, it has already identified several promising breeding lines that now are in regional trials in Mozambique, Zambia, and Zimbabwe in addition to Malawi.

We also plan to add groundnut research at or near the Sahelian Center in Niger, focusing on improvement of the crop in West Africa. Early-maturing lines from ICRISAT Center are doing well in Mali where they outyielded local cultivars.

Chickpea Advances

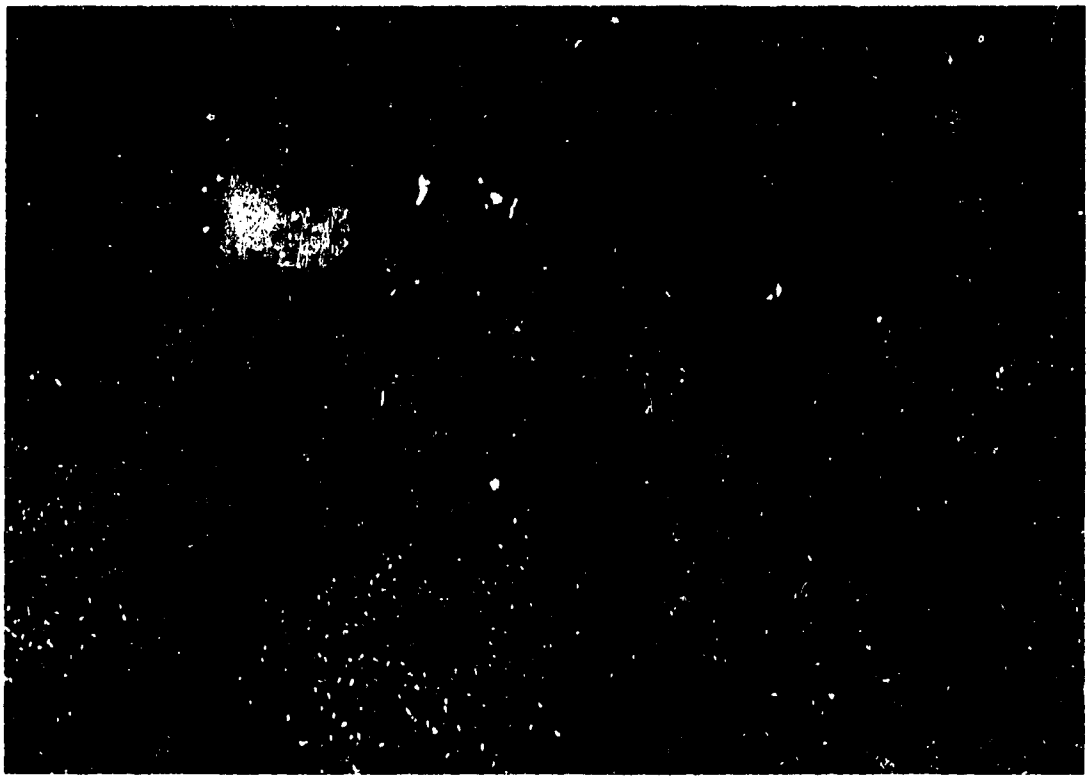
Promising chickpea lines from our research are being released in many countries of the semi-arid tropics. But the amount of ICRISAT-bred material being used by cooperators in more than 50 countries is creating an even greater impact on chickpea programs throughout the world.

Our high-yielding, medium-maturing chickpea ICCC 4 has been released in Gujarat, India by the state variety release committee after several years of testing.

ILC 482, an ascochyta blight resistant chickpea developed with our sister Institute, ICARDA, was released in Syria where it is recommended for the winter season and is expected to be released in Lebanon in the near future. Winter planting has doubled yields in Syria and other Mediterranean countries. ILC 482 was the top yielder in both winter (2020 kg/ha) and spring (1370 kg/ha) in on-farm trials by the Agricultural Research Center of Syria at 24 locations.

ILC 3279, which was second in the tests (1670 and 1050 kg/ha), is more popular with farmers because it is 50% taller, thus easier to harvest by machine, is more cold tolerant,

Chickpea harvest in Gujarat, India. ICRISAT's high-yielding, medium-maturing chickpea ICCC 4 has been released to farmers after several years of testing.



ICRISAT entry ICCC 37 was first in India's Gram Initial Evaluation Trials. Three of the top five entries in the trial were from ICRISAT.

and has stronger blight resistance. The Syrian Ministry of Agriculture has asked us to increase seeds of this line, and we expect it to be released there and in Cyprus in the near future.

IC 7357-2-3-1H-BH is proposed for release in Australia, and IC 73129-16-3-B-BH is in on-farm tests in Ethiopia. Other lines are near release in Jordan and Lebanon. Ten are in advanced trials in Nepal and Bangladesh. Several kabuli entries generated by our cooperative work with ICARDA are in multilocational and on-farm trials in Egypt, Morocco, Pakistan, Tunisia, and the USA.

In the Gram Initial Evaluation Trials in India this year, three of the four ICRISAT entries were in the top five and one, ICCC 37, was first.

Eight of our desi (small-seeded) chickpea entries are in trials for the 3rd season in India, and five kabuli (bold-seeded) types are in the Kabuli Coordinated Trials. Many others are in research-station or state trials.

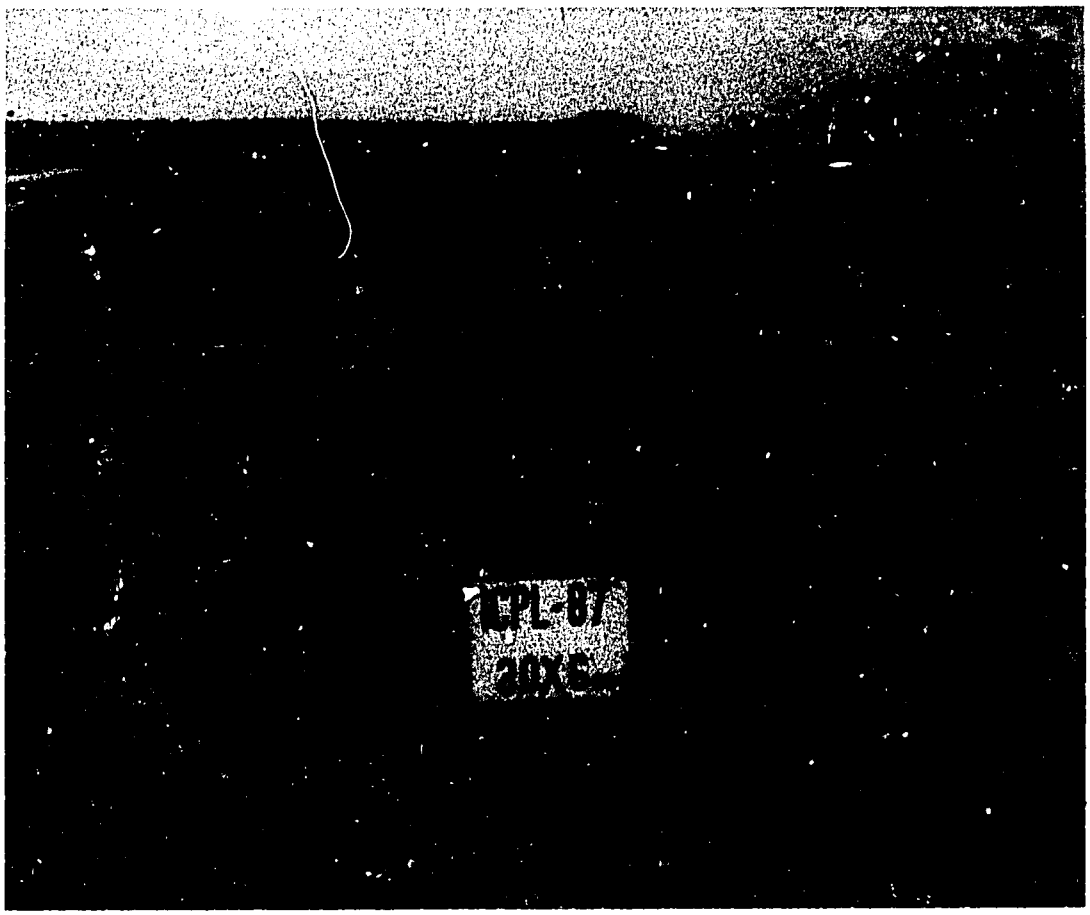
Pigeonpea Advances

Pigeonpea demonstrated great potential this year for raising the SAT farmer's standard of living.

One of our first hybrids, ICPH 2, went into intensive final tests by the Indian national program after consistently outyielding the standard checks for 4 years in advanced trials in peninsular India. Several other newer hybrids have also shown promise.

Seven lines performed well in multilocational trials of the Indian national program: ICPL 81, a very early line with high yield; ICPL 161, an early line with phytophthora resistance; ICPL 87, a widely adapted early line with large seed; ICPL 270 and 295, medium-maturing lines with resistance; ICPL 304, a medium-maturing line with wide adaptability; and ICPL 358, a late line with a

ICRISAT's early-maturing pigeonpea ICPL 87, which produced 5500 kg per hectare from three harvests this year, has wide adaptability.



very high yield potential.

Another noteworthy development in 1983 was the 5500 kg/ha production by one of our early-maturing pigeonpeas, ICPL 87, in three harvests, whereas medium-maturing pigeonpeas in peninsular India produce 2500 to 3000 kg/ha in two harvests. The three harvests of the early-maturing crops require 220 days, compared with 240 days for the two harvests from the medium-maturing crops.

ICPL 87's first flush of pods in September was 2380 kg/ha; its second harvest, 2120 kg/ha; its third, 1000 kg/ha.

Pigeonpeas proved outstanding in intercrops. Whether on deep black soils, medium-deep black soils, shallow black soils, or red soils, a pigeonpea intercrop produced the highest net returns of 13 systems studied by ICRISAT scientists.

On medium-deep black soils, pigeonpea intercropped with sorghum or millet produced much the highest net return under both low fertility and medium fertility, each exceeding Rs 4000/ha (US $400).

In shallow black soils, which lack moisture-holding capacity for sequential crops, groundnut/pigeonpea intercrop at low fertility this year gave much the highest net return of 13 systems. Each of the top four producers (each over Rs 3000/ha) included a pigeonpea intercrop. And under medium fertility where the top four exceeded Rs 5000/ha, each included pigeonpea: groundnut/pigeonpea, sorghum/pigeonpea, millet/pigeonpea, and pigeonpea alone.

More significant perhaps was pigeonpea's contribution in long-term studies of nitrogen content of soil. With no added fertilizers except an annual 15 kg/ha of phosphate, sorghum and millet yields increased during the 4 years of testing because they were intercropped with legumes (sorghum/pigeonpea and millet/groundnut, with the two intercrops alternated annually).

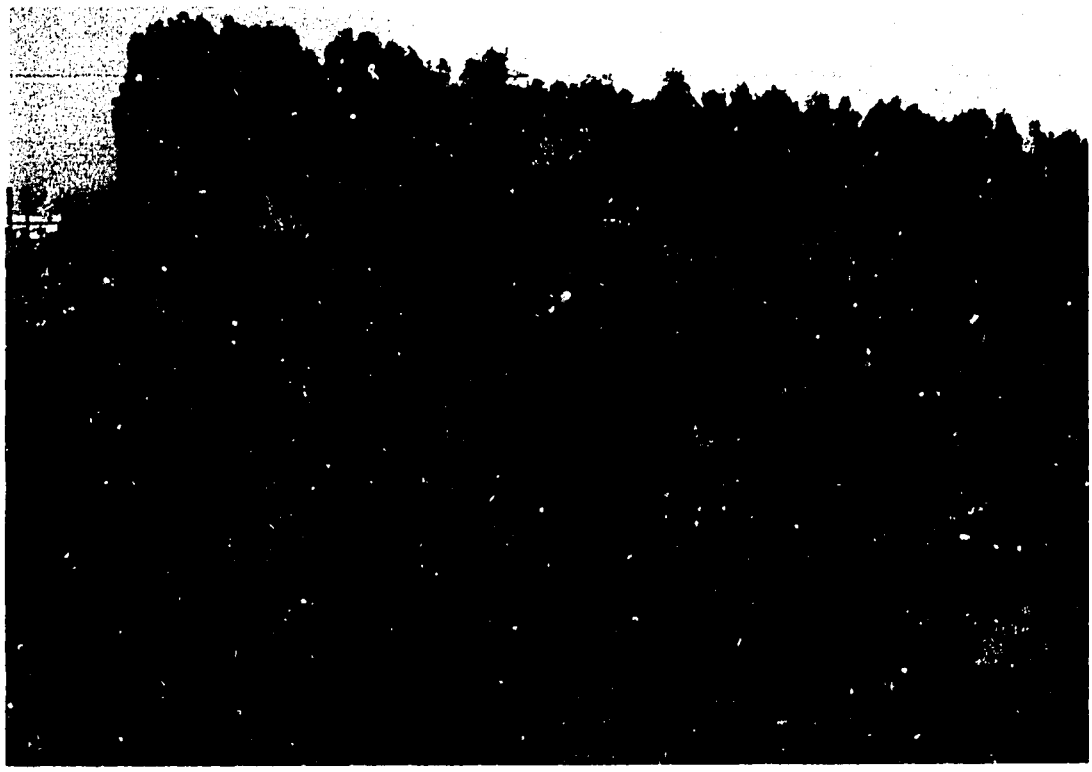
Nitrogen content of the soils did not change significantly as the legumes provided the nitrogen that sorghum or millet needed. Sorghum/pigeonpea intercrop is promising for heavier soils; millet/groundnut for light-textured soils.

Pigeonpeas are outstanding in intercrops. Here is a sorghum crop helped by pigeonpea.

We estimated that biological nitrogen fixation by the intercrops is 50 to 100 kg/ha a year. Added nitrogen increased sorghum yields only the wettest year (1981).

Intercropping was also beneficial against diseases and pests. Wilt was much less in a sorghum/pigeonpea intercrop (28%) than in sole-cropped pigeonpea (91%). During a 4-year test, the simple intercrop rotation encountered no serious pest or disease problems except for plant protection required against shoot flies on sorghum and *Heliothis* on pigeonpea.

Helping Plants Fix Nitrogen



Rhizobium *strains used as inoculants produce varying responses in chickpea. Strain R-6 at left, renamed IC 76, is now recommended to inoculant manufacturers in India.*

In earlier research at ICRISAT, we found wide differences among inoculant strains; some increased yields dramatically, others not at all, and some not enough to pay for the treatment.

Farmers buying inoculants take what is available. So an important 1983 development was the All India Coordinated Pulses Improvement Project's recommendation that India's inoculant manufacturers supply ICRISAT-identified *Rhizobium* strain IC 76 for chickpea and strain IHP 195 for pigeonpea. Both had proved superior in promoting nodulation in trials throughout India.

Nodulation, or fixing nitrogen from the air on or near plants' roots, boosts yields—the same as adding commercial nitrogen does.

Tests at ICRISAT this year showed, for example, that 88 to 96% of the nitrogen in pigeonpea tops was derived from fixation (the plant's interaction with nature).

Chickpea inoculated by *Rhizobium* strain IC 76, the one recommended to manufacturers, gave the following yield increases at locations in India: Durgapura 19%, Delhi 20%, Kanpur 6%, Dholi 25%, Varanasi 11%, Sehore 14%, Jabalpur 14%, Badnapur 11%, Gulbarga 9%. Along the same line, but with a

cereal rather than legumes, BJ 104 millet plants inoculated with a mixed culture (Napier-bajra root-enrichment) increased grain yields 26% while *Azospirillum lipoferum* increased yields of millet hybrid IP 2787 17% and of hybrid BJ 104, 12 to 24%.

When oil prices skyrocketed in the 1970s, nitrogen became prohibitively expensive for most SAT farmers, so research that helps plants take nitrogen from the air and fix it in the root zone should contribute to the welfare of such farmers.

Although the yield increases in the India tests are impressive, much remains to be learned about rhizobia. The strains function differently in different soils, and at different temperatures. Their effectiveness, in general, declines as temperatures rise. But in tests at ICRISAT Center this year, strain CM 127 was superior at 25°C; strain 120, at 32°C.

Planting inoculated seeds in sandy soils has been effective, but not in black soils. When the soil is dry, the inoculant remains on the seeds rather than moving to the root zone. Applying the inoculant in a liquid suspension improved nodulation, but chickpea is grown generally under diminishing soil moisture conditions by farmers who cannot use that method. So the progress we report for 1983 points to future research needs.

The *Rhizobium* strain NC 92 continues to give increased yields in combination with the recommended Indian groundnut cultivar Robut 33-1. It is in the final, prerelease phase of national testing.

Conserving Soil and Water

Excessive runoff and soil erosion arising from large rainstorms are a chronic problem in the SAT. So is waterlogging caused by poor infiltration. To better understand those problems and find practical solutions, ICRISAT scientists this year built a rainfall simulator and modified the contour bunding system practiced by farmers.

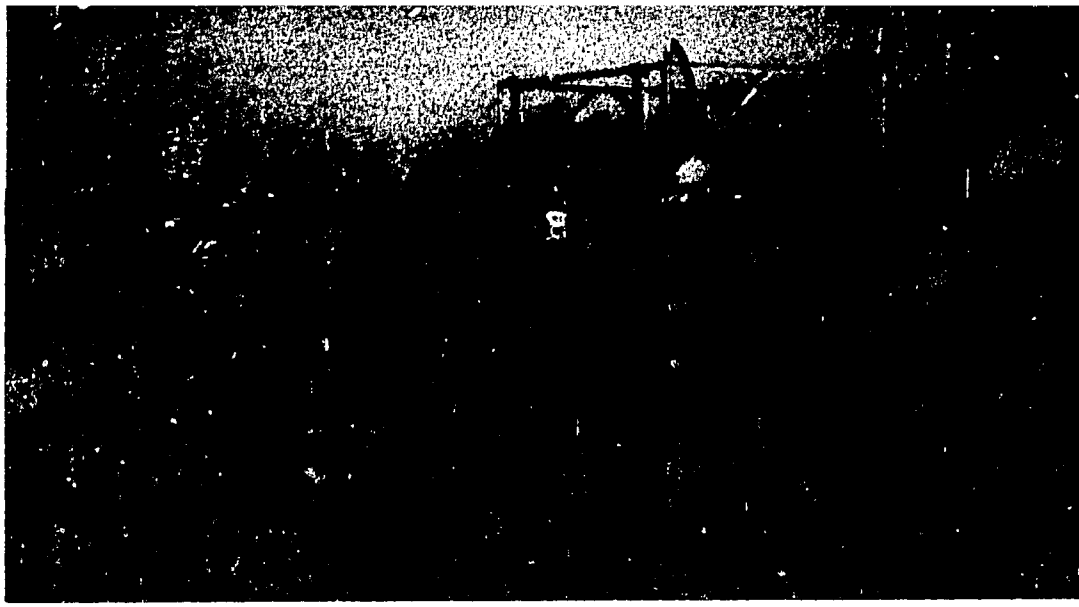
The rainfall simulator is used for controlled studies of soil and water conservation on SAT soils. With it, the scientists can create, over a small area, the required levels and intensities of rainfall, by choosing the size of raindrops and the velocity at which they hit the ground.

Adapted from a design originally used by Morin in Israel (1961), the device is made of locally available materials. The model at ICRISAT Center has an imported generator, but an indigenous one can be substituted for easier maintenance.

The portable simulator can be either machine- or bullock-drawn. It will be used primarily during the dry season to collect data on soil erosion and infiltration at given levels of rainfall. It will be used also in interdisciplinary studies on how seedlings emerge under high-impact rainstorms and on fertilizer losses owing to leaching. Sealing and crusting observations will form a major part of such studies. Both phenomena are critical.

Contour bunding is widely practiced in the semi-arid tropics, particularly on rainfed red soils with low water-holding capacity. Farmers presume that the system reduces soil erosion as it divides long slopes into smaller sections. By capturing surface runoff and letting it seep into the soil profile, the bunds increase water available for crop use.

In 5 years of testing at ICRISAT Center, we established that while contour bunds are



Rainfall simulator, built at ICRISAT Center, will be used for studies on soil and water conservation.

efficient in reducing erosion they often restrict drainage, which causes water to stagnate and reduces yields.

Based on that finding, we [illegible]ned the design of the contour bund to include gated outlets in lower sections of the field, land smoothing, and planting on grade instead of on contour. In 1983 tests, the improved system increased yields 21% over the traditional contour bund.

In the modified system, water stored above the bund is released through a gated outlet at the desired rate. Eroded sediments are deposited near the gates, and waterlogging in the fields is avoided.

Through such studies, we help farmers make better use of the soil and water resources at their disposal.

Waterlogging caused by contour bunding can be eliminated by using gated outlets (inset) in lower sections of the field. The practice conserves both soil and water.

Village Studies in Africa

Identifying socioeconomic constraints to agricultural development and determining what changes—technological and institutional—will be needed to help overcome them is a major objective of ICRISAT's research.

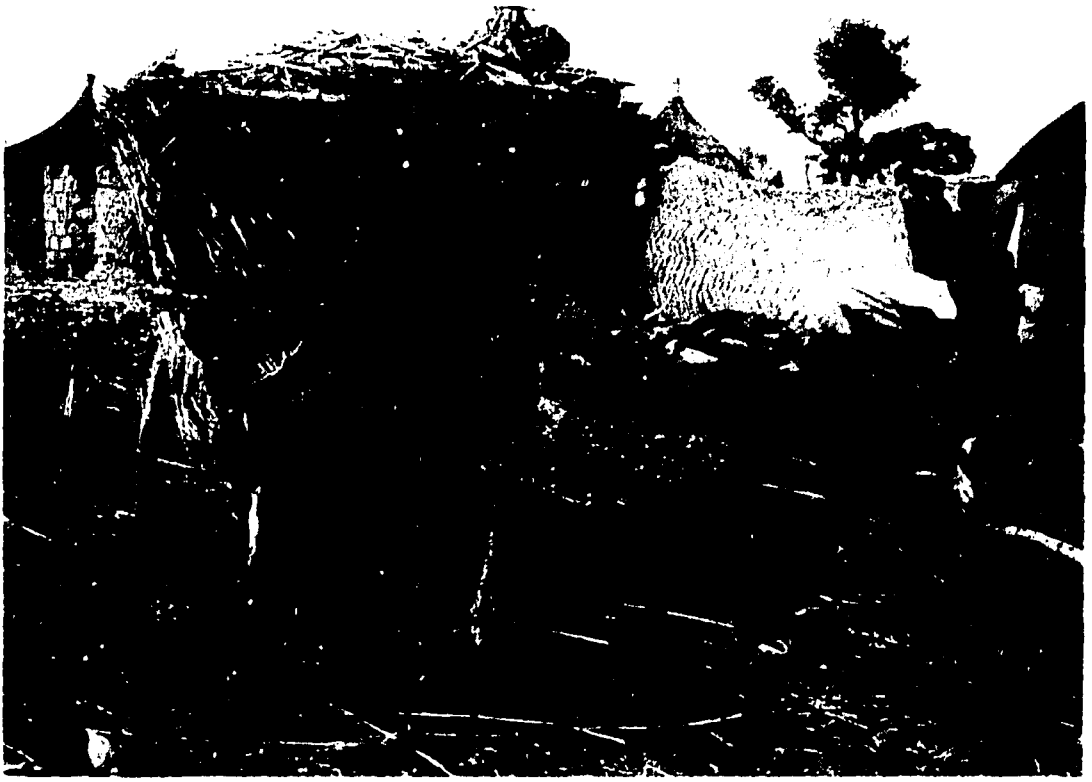
To aid directly in that process, in-depth studies are undertaken in representative SAT villages to gather and continuously revise data that describe community, culture, and ethnic factors, and to determine trends that influence agricultural decisions.

Drawing on experiences over 8 years in India, we extended such studies to villages in Niger and Upper Volta (where anthropological studies are also included) over the last 2 or 3 years. Initial results have been encouraging.

Our studies revealed some ways in which poor African farmers have learned to cope with drought and increasing population pressures: earlier maturing varieties; expansion of cropping to more marginal lands; greater use of manure or fertilizer, plows, and carts; shorter fallow periods; changing land-tenure systems to involve inheritance from father to son, replacing communal use rights.

The changes induce new pressures, especially a breakdown in herder-farmer relations. Less pasture is available for graz-

Millet heads stored in basket at Kolbila village, Upper Volta.



Farmer in Upper Volta examines grain of ICRISAT sorghum in village trial.

ing, so conflicts increase over crop damage by cattle. Shorter fallow periods impoverish the soil further. The habit of storing grain from previous years (stores of 3 to 5 years were common) gives way to relying on grain import, increasing vulnerability to drought.

While larger families are generally assumed to be more affected by drought, our studies in Upper Volta reveal the opposite. The more dependents a farmer has, the more effort he puts forth. That tentative finding is, of course, subject to many variable factors: ethnic, individual, and climatic. But heads of multiple family households produced and stored more food grain per person than heads of nuclear families. Heads of multiple family households also were more likely to invest in new technology—a result of access to pooled savings from a larger family base—and more efficient at operations involving group labor.

During times of acute stress, such as drought, the attention of an individual farmer is pulled inward to the nuclear family unit. But when better days return, the circle of sharing expands again to include a cluster of families.

Such behavioral findings have an important bearing both on future research and on adaptation of recommended practices.

Studies in Upper Volta have shown also that use of fertilizer is highly risky, especially in the more arid Sahelian zone. Without government subsidies on fertilizer (42 to 46% at present) incentives for farmers to use fertilizer would be much less than now. Among various levels of fertilizer, low rates of application gave the best returns. Being preliminary and from a year of low rainfall, these inferences will be tested again. But in the two Niger villages studied, fertilizer profitably increased yields of both the local variety and the improved cultivar.

Nutrition and Common Property

In a collaborative study on diet, health, and nutrition with India's National Institute of Nutrition and Andhra Pradesh Agricultural University's College of Home Science, ICRISAT economists found that major nutrient deficiencies in southern India were energy, calcium, β-carotene, B-complex vitamins, and ascorbic acid. Proteins and amino acids generally were not deficient. So efforts to improve protein content and quality of food grains are less important than those ensuring high and stable yields.

The energy deficit can be overcome largely by increasing available food grains, mainly cereals, the study found. Significantly, it also found that with some exceptions, nutrition programs in the SAT regions should focus on whole villages rather than on specific "vulnerable" groups within them. Greater attention to the personal care and hygiene of children would improve their nutritional status.

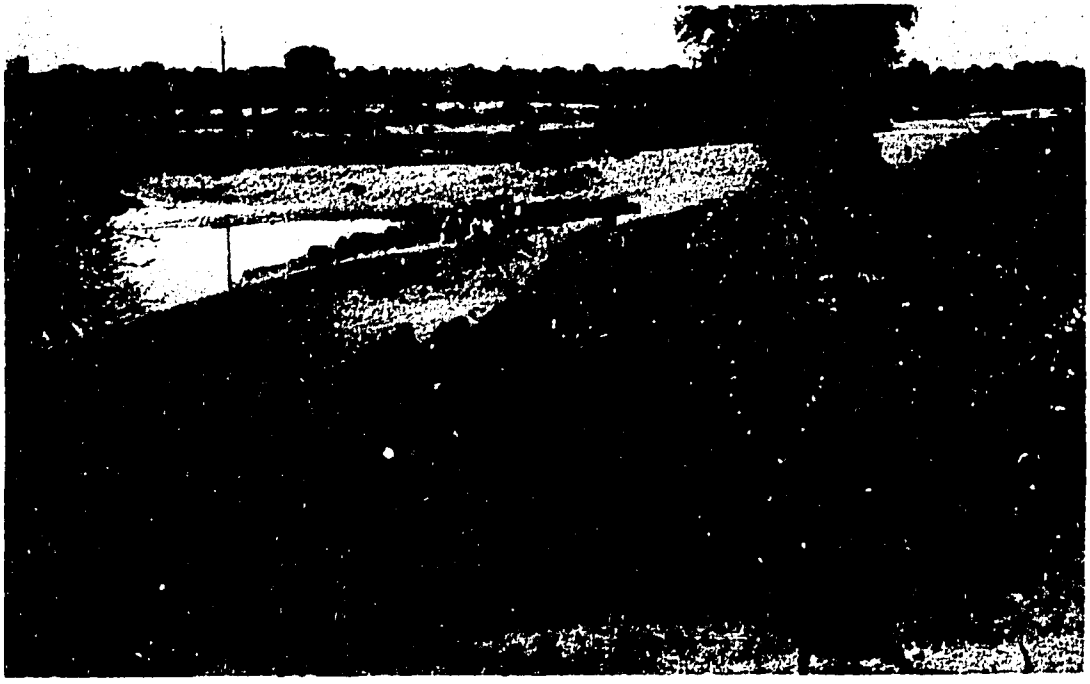
In a related study, the availability of common property resources, such as community pasture, village forest, wasteland, ponds, tanks, rivulets, watershed drains, and groundwater were found to affect nutrition, income, and employment among rural poor.

Surveying Indian villages in Andhra Pradesh and Maharashtra, we found that poor households get 8% of their nutritional intake from products of common property resources, compared with 4% for richer households. And in villages of Rajasthan and Madhya Pradesh, such products added 11 to 13% to gross income per household, a share that would rise to 30 to 48% when allowance is made for use by livestock of the open access resources. Gathering these products generates 42 to 72 man days of employment annually per household.

Despite their obvious equity value in India's villages, common property resources are declining in both area and productivity.

Nutrition study in progress. The study found that energy deficits in Indian village diets can be met largely by increasing available food grains.

Above, forage is brought home; below, sheep graze on common property. Open access resources play an important role in India's village economy, but they are dwindling.



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ICRISAT Senior Staff— as of Dec 1983

Administration

L. D. Swindale, Director General
J. S. Kanwar, Director of Research (returned from sabbatic leave April)
R. W. Gibbons, Director of Research (until April)
C. R. Jackson, Director for International Cooperation (from January)
M. G. Wedeman, Principal Administrator
S. P. Ambrose, Principal Government Liaison Officer (from June)
B. C. G. Gunasekera, Principal Soil and Water Scientist (International Cooperation)
S. J. Phillips, Special Assistant to Director General for Educational Affairs (from June)
V. Balasubramanian, Executive Officer to Director General
Joyce Gay, Administrative Secretary to Director General
Sunetra Sagar, Administrative Secretary to Director of Research
S. Krishnan, Senior Administrative Officer (International Cooperation)
D. Mitra, Fiscal Manager
A. Banerji, Assistant Manager (Fiscal)
V. S. Swaminathan, Senior Accounts Officer
A. N. Venkataswamy, Accounts Officer
C. P. Rajagopalan, Accounts Officer
B. K. Johri, Personnel Manager
N. S. L. Kumar, Senior Personnel Officer
P. Suryanarayana, Personnel Officer
R. Vaidyanathan, Purchase and Stores Manager
K. P. Nair, Senior Purchase Officer
D. K. Mehta, Stores Officer
D. V. Rama Raju, Purchase Officer
K. C. Saxena, Stores Officer
K. R. Natarajan, Shipping and Purchase Officer
S. K. Dasgupta, Senior Scientific Liaison Officer (Visitors' Services)
A. Lakshminarayana, Scientific Liaison Officer (Visitors' Services)
K. K. Sood, Security Officer
K. K. Vij, Senior Administrative Officer (Delhi Office)
V. Lakshmanan, Assistant Manager (Administration)
N. Suryaprakash Rao, Resident Medical Officer
R. Narsing Reddy, Transport Officer (until September)
G. Vijayakumar, Transport Officer (from October)

International Cooperation

M. Tardiou, Coordinator of Programs, West Africa
K. F. Nwanze, Principal Millet Entomologist and Acting Team Leader, Niger
D. C. Goodman, Administrative Officer, Niger (from November)
K. Anand Kumar, Principal Millet Breeder, Niger
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
M. C. Klaij, Principal Soil and Water Engineer, Niger (from November)
A. Bationo, Soil Scientist (ICRISAT/IFDC), Niger
R. Chase, Soil Scientist (Texas A&M University), Niger
B. Christianson, Soil Scientist (ICRISAT/IFDC), Niger
Maimouna S. Dicko, Animal Nutritionist (ICRISAT/ILCA), Niger
C. M. Pattanayak, Principal Sorghum Breeder and Team Leader, Upper Volta
A. J. Dagenais, Administrative Officer, Upper Volta (until May)
K. V. Ramaiah, Principal Cereal Breeder—*Striga*, 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, Upper Volta
Helga Vierich, Principal Social Anthropologist, Upper Volta
W. Stoop, Senior Research Officer (ICRISAT/ISNAR), Upper Volta
S. C. Gupta, Principal Millet Breeder, Senegal
J. F. Scheuring, Principal Cereals Breeder, Mali
P. G. Serafini, Principal Cereals Agronomist, Mali
M. K. O'Neill (International Intern), Mali
S. O. Okiror, Principal Millet Breeder and Team Leader, Nigeria
N. G. P. Rao, Principal Sorghum Breeder, Nigeria (until June)
J. H. MacFarlane, Principal Cereals Entomologist, Nigeria
S. V. R. Shetty, Principal Agronomist, Nigeria (from February)

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Brhane Gebrekidan, ICRISAT/SAFGRAD Coordinator for Sorghum and Millet, Eastern and Southern Africa, Kenya
R. P. Jain, Principal Millet Breeder, Sudan
Gebisa Ejeta, Principal Sorghum Breeder, Sudan (until December)
K. R. Bock, Principal Groundnut Pathologist and Team Leader, Malawi (from December)
S. N. Nigam, Principal Groundnut Breeder, Malawi
V. Y. Guiragossian, Principal Sorghum Breeder, Mexico
C. L. Paul, Principal Sorghum Agronomist, Mexico
K. B. Singh, Principal Chickpea Breeder, Syria
M. V. Reddy, Principal Chickpea Pathologist, Syria

Research Programs

Sorghum

L. R. House, Principal Plant Breeder and Leader
S. Z. Mukuru, Principal Plant Breeder
L. K. Mughogho, Principal Plant Pathologist
J. M. Peacock, Principal Plant Physiologist
K. Leuschner, Principal Cereal Entomologist
Bhola Nath Verma, Plant Breeder
D. S. Murty, Plant Breeder
B. L. Agrawal, Plant Breeder
Belum V. S. Reddy, Plant Breeder
M. J. Vasudeva Rao, Plant Breeder (until September)
N. Seetharama, Plant Physiologist
R. K. Maiti, Plant Physiologist (on sabbatic leave)
Suresh Pande, Plant Pathologist
R. Bandopadhyay, Plant Pathologist
S. L. Taneja, Entomologist
H. C. Sharma, Entomologist
S. P. Jaya Kumar, Administrative Officer
Rama (Research Fellow)

Pearl Millet

D. J. Andrews, Principal Plant Breeder and Leader
L. A. Hunt, Principal Plant Breeder (until June)
F. R. Bidinger, Principal Plant Physiologist (on sabbatic leave from May)
R. J. Williams, Principal Plant Pathologist (until February)
S. B. King, Principal Plant Pathologist (from June)
P. J. Dart, Principal Cereal Microbiologist (until September)
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
K. R. Krishna, Microbiologist
Nirmala Kumar, Administrative Officer
Judith A. Kipe-Nolt (International Intern)

Pulses

Y. L. Nene, Principal Plant Pathologist and Leader (on sabbatic leave until April)
D. G. Faris, Principal Plant Breeder, Pigeonpea
W. Reed, Principal Entomologist
J. B. Smithson, Principal Plant Breeder, Chickpea
J. A. Thompson, Principal Pulse Microbiologist
J. Arihara, Assistant Physiologist, Pulses (Visiting Scientist, TARC)
D. Sharma, Senior Plant Breeder, Pigeonpea
K. C. Jain, Plant Breeder, Pigeonpea (on sabbatic leave from August)
K. B. Saxena, Plant Breeder, Pigeonpea
S. C. Gupta, Plant Breeder, Pigeonpea
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
S. P. S. Beniwal, Senior Plant Pathologist
M. P. Haware, Plant Pathologist
J. Kannaiyan, Plant Pathologist (on leave from December)
O. P. Rupela, Microbiologist
J. V. D. K. Kumar Rao, Microbiologist
D. M. Pawar, Agricultural Officer
M. D. Gupta, Senior Research Associate
V. S. Bisht (Research Fellow)
D. R. Dent (International Intern)
J. H. Mareck (International Intern)
S. B. Sharma (Research Fellow)
Harjit Singh (Research Fellow)

Groundnut

R. W. Gibbons, Principal Plant Breeder and Leader (on sabbatic leave from April)
D. McDonald, Principal Plant Pathologist and Leader
D. V. R. Reddy, Principal Plant Virologist (on sabbatic leave from May)
J. H. Williams, Principal Plant Physiologist
J. P. Moss, Principal Cytogeneticist
A. M. Ghanekar, Plant Virologist

L. J. Reddy, Plant Breeder
P. Subrahmanyam, Plant Pathologist
M. J. Vasudeva Rao, Plant Breeder (from October)
V. M. Ramraj, Plant Physiologist (from October)
V. K. Mehan, Plant Pathologist
K. Tanaka, Biochemist (Visiting Scientist, TARC)
M. Saito, Mycologist (Visiting Scientist, TARC)
P. T. C. Nambiar, Microbiologist
P. W. Amin, Entomologist
A. K. Singh, Cytogeneticist
D. C. Sastri, Cytogeneticist
S. L. Dwivedi, Plant Breeder
R. C. Nageswar Rao, Plant Physiologist
A. B. Mohammed, Entomologist
Mohinder Pal, Plant Physiologist (until January)
Y. Bhaskar, Assistant Engineer
P. Subrahmanyam, Administrative Officer
S. N. Azam-Ali, (International Intern)
T. N. Bhavani Shankar (Research Fellow)
M. Dutta (Research Fellow)
B. L. Nolt (International Intern)
Rasheedunisa (Research Fellow)
G. Rajendrudu (Research Fellow)

Farming Systems

S. M. Virmani, Principal Agroclimatologist and Leader
R. W. Willey, Principal Agronomist (on sabbatic leave until September)
C. W. Hong, Principal Soil Scientist (ICRISAT/IFDC)
S. A. El-Swaify, Principal Soil Scientist
G. E. Thierstein, Principal Agricultural Engineer (on sabbatic leave from December)
T. Takenaga, Principal Agricultural Engineer (ICRISAT/JICA) (from August)
J. R. Burford, Principal Soil Chemist
M. V. K. Sivakumar, Principal Agroclimatologist
Y. Nishimura, Principal Assistant Agronomist (ICRISAT/JICA) (until November)
R. Busch, Principal Soil Scientist (ICRISAT/Justus Leibig University)
M. Wurzer, Principal Assistant Soil Scientist (ICRISAT/University of Hamburg)
S. V. R. Shetty, Agronomist (until January)
Piara Singh, Soil Scientist
Sardar Singh, Soil Scientist
T. J. Rego, Soil Scientist
K. P. R. Vittal, Soil Scientist (from June)
K. L. Sahrawat, Soil Chemist (on sabbatic leave from July)
A. K. S. Huda, Agroclimatologist
M. R. Rao, Agronomist (on sabbatic leave)
M. S. Reddy, Agronomist
M. Natarajan, Agronomist
R. C. Sachan, Agricultural Engineer
K. L. Srivastava, Agricultural Engineer
R. K. Bansal, Agricultural Engineer
C. S. Pawar, Entomologist
S. K. Sharma, Senior Research Associate
Siloo Nakra, Executive Assistant (until March)
Surendra Mohan, Administrative Officer
A. A. H. Khan, Senior Research Associate (Engineering)
S. Ramachandran, Senior Secretary
R. T. Hardiman (International Intern)
G. M. Heinrich (International Intern)

Economics

M. von Oppen, Principal Economist and Leader
J. G. Ryan, Principal Economist (until May)
T. S. Walker, Principal Economist (ICRISAT/ADC)
N. S. Jodha, Senior Economist
R. D. Ghodake, Economist
R. P. Singh, Economist
K. N. Murthy, Economist (until September)
R. S. Aiyer, Senior Administrative Officer
K. G. Kshirsagar, Senior Research Associate
K. V. Subba Rao, Senior Research Associate

Support Programs

Biochemistry

R. Jambunathan, Principal Biochemist (on sabbatic leave from July)
Umaid Singh, Biochemist
V. Subramanian, Biochemist (on leave from May)
Santosh Gurtu, Senior Research Associate

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 (on sabbatic leave from June)

Plant Quarantine

B. K. Varma, Chief Plant Quarantine Officer
Upendra Ravi, Senior Research Associate
N. Rajamani, Senior Administrative Officer

Fellowships and Training

D. L. Oswalt, Principal Training Officer
A. S. Murthy, Senior Training Officer
B. Diwakar, Senior Training Officer
T. Nagur, Training Officer
A. Prakash Rao, Training Officer
T. A. Krishnamurthi, Senior Administrative Officer

Information Services

H. L. Thompson, Head
J. B. Wills, Research Editor
Susan D. Feakin, Research Editor (from June)
C. A. Giroux, French Writer/Editor
S. M. Sinha, Assistant Manager (Art and Production)
S. Varma, Editor (on leave from April)
D. R. Mohan Raj, Editor (from February)
N. Raghavan, Editor (from July)
H. S. Duggal, Senior Photographic Supervisor
G. K. Guglani, Art Visualizer
T R. Kapoor, Composing Supervisor
P. E. Stephen, Printshop Supervisor

Statistics

B. Gilliver, Principal Statistician
Murari Singh, Statistician

Computer Services

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

Library and Documentation Services

S. Dutta, Manager (Library and Documentation Services)
P. K. Sinha, Senior Documentation Officer
P. S. Jadhav, Library Officer
S. Prasannalakshmi, Library Officer

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, Assistant Manager (Warehouse)

Physical Plant Services

E. W. Nunn, Station Manager
F. J. Bonhage, Construction Supervising Officer (until July)
P. M. Menon Senior Administrative Officer
Sudhir Rakhra, Chief Engineer (Civil)
D. Subramanyam, Chief Engineer (Electrical)
B. K. Sharma, Senior Engineer (until April)
U. B. Culas, Manager (Workshop)
S. K. V. K. Chari, Senior Engineer (Electronics and Instrumentation)
N. S. S. Prasad, Senior Engineer (from February)
A. R. Das Gupta, Senior Engineer (Communication)
D. C. Raizada, Senior Engineer (Airconditioning)
N. V. Subba Reddy, Horticulture Officer
D. V. S. Verma, Engineer (Machineshop)
R. Thiyagarajan, Engineer (Automobiles)
A. N. Singh, Engineer (Heavy Equipment and Tractors)
S. W. Quadar, Engineer (Office Equipment)
K. Mohan, Engineer (Civil) (from November)

Farm Development and Operations

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