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ICRISAT Research Highlights

1989

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Cover: *Evaluation of African perennial pigeonpea lines for fodder production on an Alfisol in the dry season at ICRISAT Center. Seen evaluating are a Postdoctoral Fellow from Uganda and an ICRISAT scientist.*

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Introduction

With good rains in 1989, the farmers of the semi-arid tropics contributed significantly to the economic growth of their countries. ICRISAT contributed to this progress by providing improved technology and through cooperation with national programs in the transfer of technology from laboratories and experimental plots to farmers. ICRISAT helped farmers to increase food grain production in India and is beginning to have an impact on sustainable food production in Africa.

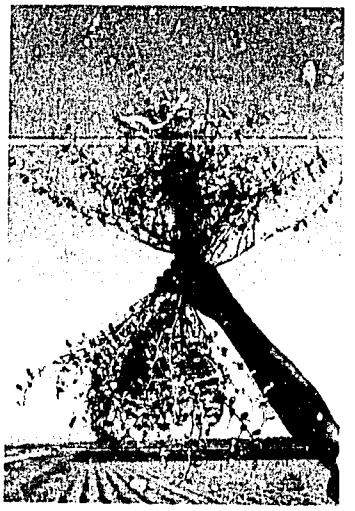
Plant materials from each of our five mandate crops were released in several parts of the world. In western Africa, varieties of pearl millet developed by ICRISAT in collaboration with national programs are gradually spreading into farmers' fields. In Asia, too, genotypes of ICRISAT's mandate crops were well received. In India, a groundnut variety ICGV 87141 (ICGS 76) and a short-duration pigeonpea ICPL 151 (Jagriti) were released, while two sorghum varieties (ICSV 743 and ICSV 745), a pigeonpea selection ICPL 332 (Abhaya), and two chickpea varieties (ICCV 2 and ICCC 37) were approved for regional use. In Pakistan, BARD 699, a selection from ICRISAT's groundnut material, was released to farmers.

ICRISAT focused attention on the sustainability of agriculture in the semi-arid tropics and a sustainability perspective will become increasingly important in all our research and training. ICRISAT scientists identified perennial pigeonpea lines with promise in agroforestry systems. In western Africa, we confirmed that growing pearl millet in rotation with legumes such as cowpea or groundnut is beneficial in the Sahelian and the Sudanian zones.

ICRISAT scientists working in southern Africa have further consolidated their cooperation with national programs on sorghum and millets. In recent years, improved germplasm materials from ICRISAT have found acceptance in several countries in the region. The expansion of ICRISAT's work in crop utilization, food technology, market economics, and input into forage studies is significant.

We hope the results of ICRISAT's work continue to be of value to the farmer in reaping richer harvests.

L.D. Swindale
Director General



ICRISAT chickpea variety ICCV 2 released in Andhra Pradesh, India.

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

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.

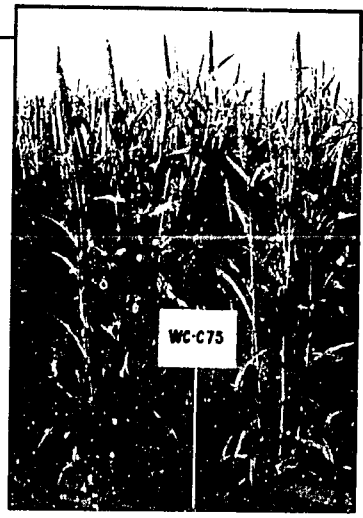
The SAT is a harsh region of limited, erratic rainfall and nutrient-poor soils. It is populated by over 750 million people, most of whom live at subsistence levels and depend for their food on the limited production of small farms.

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

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

ICRISAT's mandate is to:

1. Serve as a world center for the improvement of grain yield and quality of sorghum, millet, chickpea, pigeonpea, and groundnut and to act as a world repository for the genetic resources of these crops;
2. Develop improved farming systems that will help to increase and stabilize agricultural production through more effective use of natural and human resources in the seasonally dry semi-arid tropics;
3. Identify constraints to agricultural development in the semi-arid tropics and evaluate means of alleviating them through technological and institutional changes; and
4. Assist in the development and transfer of technology to the farmer through cooperation with national and regional research programs, and by sponsoring workshops and conferences, operating training programs, and assisting extension activities.



Pearl millet variety ICMV 1 (WC-C75), growing at ICRISAT Center, an example of durability of resistance to downy mildew in open-pollinated varieties.

Successes in Plant Improvement

New varieties and hybrids are not developed overnight. On an average, 8 years of hard work by ICRISAT scientists from various disciplines, followed by up to 4 years of testing by national program scientists, may pass before a hybrid or a variety is released for cultivation. Even then the acceptance of an improved variety by farmers is uncertain.

ICRISAT's attempts in promoting farmers' acceptance of its released material have been fairly successful in recent years. Pearl millet variety ICMV 1, popularly known as WC-C75, was released in India in 1982. Largely because of its good resistance to the downy mildew *(Sclerospora graminicola)* disease, this cultivated variety has become so popular in India that it will be sown on an estimated 1 million ha in 1990.

In 1989, ICRISAT scientists noted with satisfaction that WC-C75 continues to maintain its very low level (less than 5%) of downy mildew infection across India 13 years after it first entered all-India testing, showing the durability of resistance in open-pollinated varieties.

ICRISAT scientists' breeding success was repeated with millet variety ICMV 155 (ICMV 84400). It matures as quickly as WC-C75 and outyielded WC-C75 by 12% in 89 All India Trial locations. ICMV 155 was developed from the New Elite Composite by recurrent selection.

During 1989, ICRISAT supplied 1.6 t of breeders' seed of pearl millet in response to 440 individual requests from public and private seed companies in India. This quantity of seed is sufficient to sow approximately 5000 ha of seed-production fields.

Finger millet trials at Kasama, Zambia. An ICRISAT finger millet variety SDFM 217 was released this year as Lima in Zambia.

ICRISAT scientists established that it is not always necessary for both parents of pearl millet hybrids to have high levels of resistance to downy mildew disease to give good yield. The resistance of a hybrid is generally as good as its most resistant parent.

Pearl millet breeders in the Southern African Development Coordination Conference (SADCC) region were successful in having ICRISAT-improved material adopted for release in some countries of southern Africa. ICRISAT contributed a pearl millet line to Namibia, where cooperative efforts by ICRISAT scientists in Zimbabwe and those of the Rossing Foundation Agricultural Training Centre at Okashana led to the release of ICTP 8203 under the name Okashana 1 in the millet-growing region of Namibia. Farmers traveled as far as 200 km to buy seeds of the new variety and 200 t of seed has already been multiplied and sold by the Training Centre. This variety was bred at ICRISAT Center.

ICRISAT Zimbabwe-based scientists also helped release another variety (ICMV 82132) which was bred at ICRISAT Center for the SADCC region. It was released in Zambia this year as Kaufela.

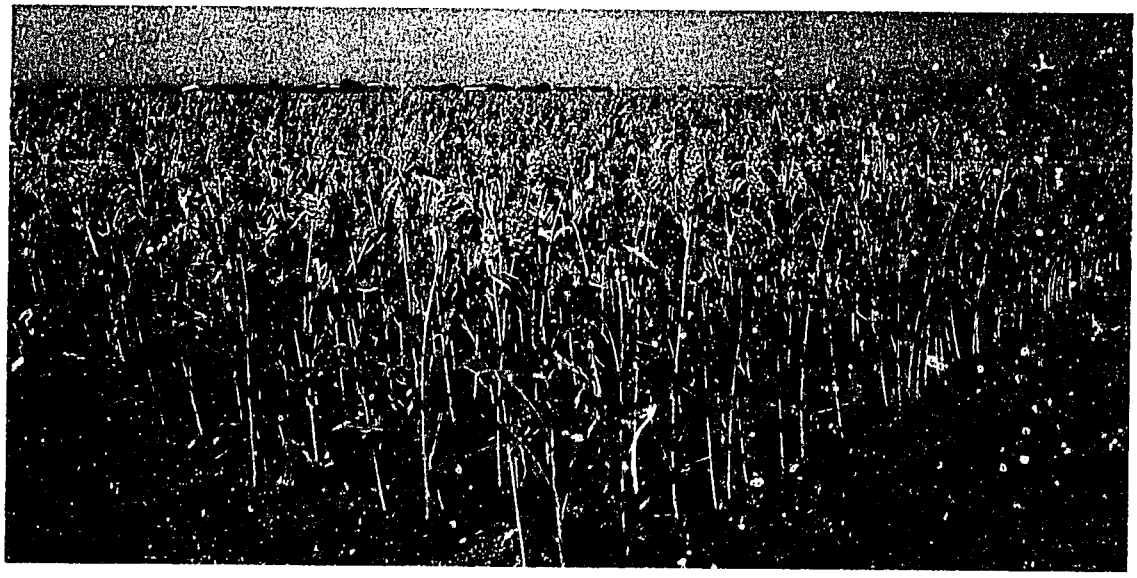
Another success was the release in Zambia of a finger millet variety SDFM 217 under the name Lima. This finger millet originated from germplasm accessions collected in Malawi by ICRISAT scientists.

In research on sorghum, ICRISAT breeders also had considerable success this year. Two agronomically superior midge-resistant sorghum varieties, ICSV 743 and ICSV 745, were adopted by the Department of Agriculture, Karnataka, India, for distribution to farmers in midge-endemic areas. These varieties were reported to be doing extremely well in this Indian state (*see page 21*).

In India, three sorghum hybrids (ICSH 86646, ICSH 86647, and ICSH 86749) were promoted to the postrainy *(rabi)* season advanced trials of the All India Coordinated Sorghum Improvement Project. Their grain

Pearl millet variety ICMV 155, also called ICMV 84400, recommended for release in India, growing at ICRISAT Center.

ICSV 745, a midge-resistant sorghum, released in Karnataka, India, growing at ICRISAT Center.



yields were 0.4 to 0.6 t/ha higher than the control hybrid CSH 12 R.

In southern Africa, two selections from ICRISAT sorghum introductions, SDS 1513 and SDS 1594, were released in Swaziland this year. These are both red sorghums. Two ICRISAT varieties have been released in Mozambique—MACIA (selected from SDS 3220) and MAMONHE (selected from IS 8571). An ICRISAT cultivar, released earlier in India (ICSV 112), has been identified for prerelease in Malawi, while SPV 351 (ICSV 1) was released this year.

In western Africa, ICRISAT sorghum scientists based in Nigeria selected two ICRISAT-bred sorghum hybrids (ICSH 507 and ICSH 780) that yielded more than 5 t/ha in trials across several locations.

On the other side of the Atlantic, in the ICRISAT Mesoamerican Variety Trial, ICSV 112 was the highest yielder (mean 5.62 t/ha) at seven locations and was released in Mexico as Pacífico and in Nicaragua as Pinolero 1.

ICRISAT legumes reached farmers in many different countries as successfully as did ICRISAT cereals. Two ICRISAT chickpea varieties were released in Andhra Pradesh, India, this year. ICCC 37, a short-duration desi-type chickpea with good resistance to fusarium wilt race 1 and moderate resistance to dry root rot, was released by the Andhra Pradesh Ministry of Agriculture under the name Kranthi (which means revolution). With irrigation, this variety can yield more than 3 t/ha. Chickpea variety ICCV 2 was also released to farmers on the approval of the Andhra Pradesh Ministry of Agriculture in 1989 as Swetha (which means white). This was the first kabuli type with resistance to fusarium wilt to be released for cultivation in peninsular India. It yields more than 1 t/ha on residual moisture following an average rainy season, while yields of 2 to 3 t/ha can be achieved with irrigation.

ICRISAT chickpea breeders developed wilt-resistant, extra-short-duration desi varieties ICCV 88201 and ICCV 88202, and evaluated them

An ICRISAT scientist (far right), *a farmer, and the coordinator* (far left) *of the Guatemalan national sorghum program in a sorghum field near Tiucal, Guatemala.*

Profusely podding pigeonpea ICPL 332 (Abhaya) released in Andhra Pradesh, India.

in a rainfed field where they yielded over 1 t/ha in 86 days. The seeds are yellowish, attractive, and medium sized, and are expected to prove popular in drought-prone environments because they mature early.

In the northern parts of the Indian subcontinent, farmers tend to grow chickpea after rice, cotton, or maize. If these crops are harvested late, chickpea is also sown late. ICRISAT scientists succeeded in combining high yield under late-sown conditions and resistance to diseases such as wilt, ascochyta blight, and stunt, as well as to the pod-boring insect pest

Chickpea variety ICCV 2 growing in a farmer's field in Maharashtra, India.

Evaluation of short-duration pigeonpea lines at ICRISAT Center.

*Groundnut ICGV 87141 (ICGS 76) (*inset*) released in India growing in a farmer's field in Maharashtra, India.*

Groundnut scientists of the Pakistan national program discussing the advantages of the variety BARD 699 released in Pakistan.

Helicoverpa armigera. In an advanced trial at Hisar, Haryana, two ICRISAT lines (ICCL 89861 and ICCL 89862) gave yields similar to the control Pant G 114 and exhibited the desired combined resistance. At Gwalior, in Madhya Pradesh, ICRISAT lines yielded 3 t/ha, comparing favorably with 2.3 t/ha by the control.

Two ICRISAT/ICARDA (International Center for Agricultural Research in the Dry Areas) chickpea lines (ILC 5566 and FLIP 85-17C) were selected this year from the ICRISAT/ICARDA international nurseries and released in Portugal as cultivated varieties—ILC 5566 as Elmo, and FLIP 85-17C as Elvar.

This year in Andhra Pradesh—where farmers have suffered from the devastation of crops by the *H. armigera* that also affects pigeonpea—a high-yielding ICRISAT pigeonpea line ICPL 332 with good tolerance for *Helicoverpa* damage was released in the state as Abhaya (which means fearless). It performs well even when pesticides are not used. Another ICRISAT pigeonpea line, ICPL 151, was released in India as Jagriti.

Both ICRISAT groundnut scientists and Indian farmers were pleased with the release of ICGV 87141 (ICGS 76) for rainy-season cultivation in India. It is a virginia bunch variety that has two-seeded, medium-sized pods, and recovers well after mid-season drought. It is suitable for cultivation in Andhra Pradesh, Tamil Nadu, Karnataka, and Kerala.

In Pakistan, the National Agricultural Research Centre's Varietal Evaluation Committee approved the release of the groundnut variety BARD 699 for rainfed cultivation. BARD 699 is a composite variety derived from ICRISAT groundnut selections ICGV 87128 (ICGS 44) and ICGV 87187 (ICGS 37).

The Republic of Korea released a selection from ICRISAT groundnut variety ICGV 87127 (ICGS 35) as Jinpungtangkong; its seed has high oil (52.3%) and protein (23.2%) contents.

A pigeonpea line isolated for terminal clusters of pods during FONAIAP/ ICRISAT joint germplasm evaluation in Venezuela.

Germplasm Collection, Evaluation, and Distribution: Potential and Milestones

The new high-yielding crop varieties and hybrids finding acceptance in farmers' fields are derived through breeding from landraces (traditional varieties) found in farmers' fields, as well as their close wild relatives. This rich source of raw material, which is the foundation of all crop improvement research, is maintained in gene banks, such as the one at ICRISAT Center. So far only a fraction of the conserved germplasm in this international repository has been used in crop improvement programs.

The key to solving present and future problems of hunger in the semi-arid tropics lies within the diversity and availability of germplasm. A total of 99 790 accessions of ICRISAT mandate crops and minor millets have been collected from some 128 countries, and meticulously evaluated, documented, and conserved over the past 15 years.

The challenges of seed collection continue. In 1989, ICRISAT scientists were able to add 3282 accessions of mandate crops and 308 of minor millets from the Central African Republic, India, Indonesia, Malawi, Pakistan, and Togo in collaborative efforts with various national institutions of these countries.

An ICRISAT botanist (far right) *and a scientist of the National Bureau of Plant Genetic Resources* (center) *collecting sorghum germplasm in Madhya Pradesh, India, during a collaborative collection mission.*

Selecting large spikes with large grain from an early-maturing pearl millet field in Togo.

An ICRISAT botanist collecting chickpea germplasm in Malawi.

In collaboration with the Ministry of Rural Development, the Central African Republic, an ICRISAT botanist collected 129 pearl millet germplasm samples in 1989. The material is a promising source of white grain color. In collaboration with the Department of Agricultural Research of Togo, 480 germplasm samples of pearl millet were collected. They have potential as a source of large grain and early-maturing traits.

An ICRISAT botanist (wearing cap) *gathering information from farmers in the Central African Republic.*

FONAIAP/ICRISAT joint pigeonpea germplasm evaluation at Quibor, Venezuela.

ICRISAT evaluated 500 accessions of pigeonpea germplasm in collaboration with the Fondo Nacional de Investigaciones Agropecuarias (FONAIAP) of Venezuela in the quest for medium-duration vegetable pigeonpea suitable for the postrainy season in areas where supplemental irrigation is available. ICRISAT staff conducted another collaborative pigeonpea germplasm evaluation in eastern Africa with the active participation of the National Dryland Farming Research Centre, Kenya. Here, too, care was taken to select vegetable types with good agronomic traits and the desired maturity. Because Kenya and Venezuela have similar agroclimatic environments, the best entries from both countries are being evaluated by the Kenyan centre. Entries that perform well in multilocational testing in Kenya are likely to be released there.

When the long-term storage facility at ICRISAT Center became operational in 1989, ICRISAT botanists shifted their priority to systematic rejuvenation of the accessions and seed multiplication. Over 15 000 cultivated accessions and over 200 wild relatives of sorghum were rejuvenated.

Germplasm evaluation continued at ICRISAT Center as well as in Cameroon, India, Kenya, Nigeria, and Venezuela. In India, joint evaluation of germplasm at various locations was conducted in collaboration with scientists of the National Bureau of Plant Genetic Resources and other crop improvement scientists.

Passport and evaluation data were painstakingly compiled this year for over 7000 sorghum, 3000 pearl millet, 350 chickpea, and 2000 groundnut accessions and these were entered into the ICRISAT Data Management and Retrieval System. Computer printouts containing genetic information were supplied on request to various research organizations.

Equal in importance to the collection of germplasm is its distribution to scientists working on ICRISAT's mandate crops throughout the world. Over 60 000 germplasm samples were distributed in 1989, of which over 11 000 samples were supplied to ICRISAT scientists, over 32 000 samples to the Indian national programs, and over 17 000 to scientists elsewhere.

Collection of groundnut germplasm from a mixed crop of sugarcane and groundnut in Indonesia.

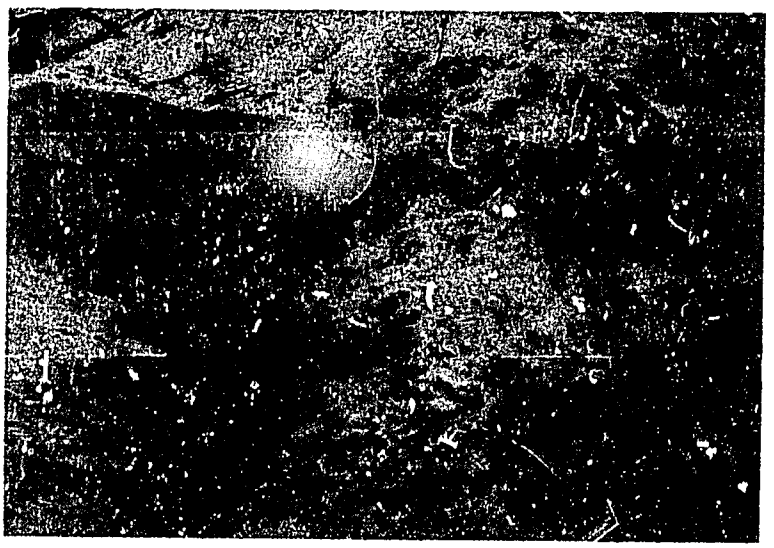
Towards Better Plant Survival in Harsh Environments

A cluster of Striga hermonthica *flowers.*

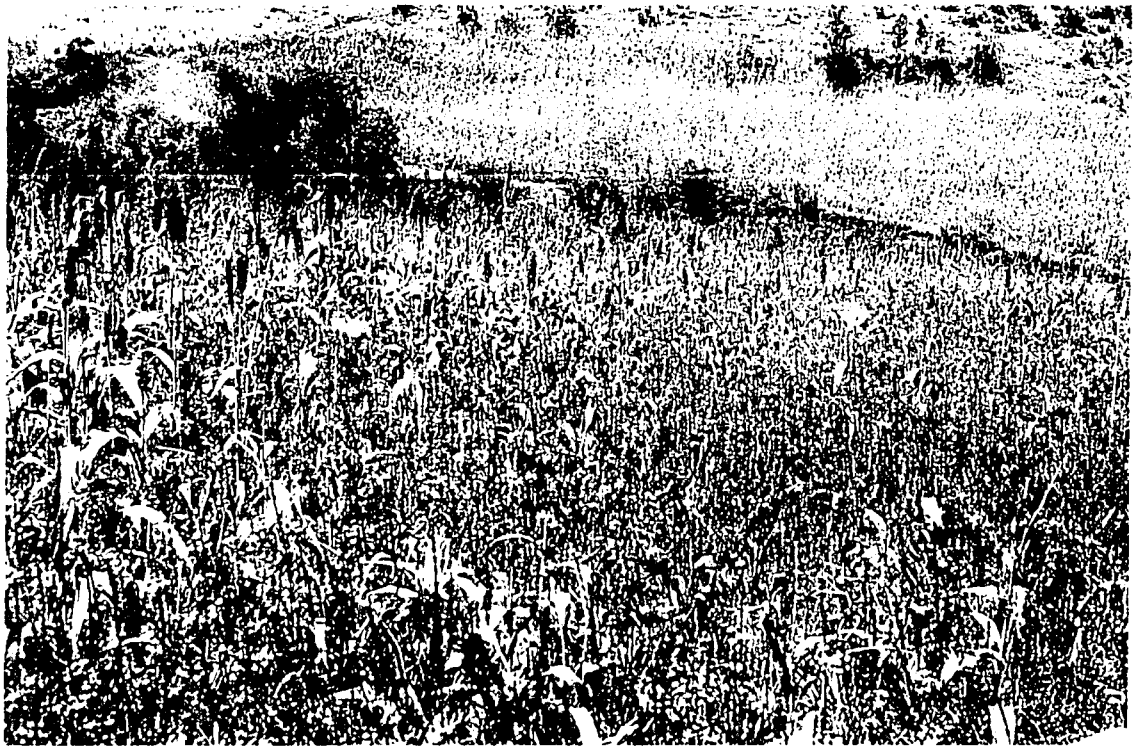
Rarely are conditions in the semi-arid tropics continuously favorable during the cropping season. Farmers here toil in environments plagued by insufficient and sporadic rainfall, high soil and air temperatures, and nutrient-poor soils—any of which can result in crop failure. Under such adverse environmental conditions, the intervention of agricultural science to avoid a famine can be important.

In these harsh environments, seedling emergence is a crucial factor. The percentage of germinating seeds out of the total sown by the farmer becomes vital. In the past, ICRISAT scientists studied the factors favorable for germination of pearl millet seeds under stress conditions. However, as seedling emergence, even under comparatively favorable conditions, is often as low as 50% of seeds sown, they turned their attention to genetic selection to increase the percentage of emerging pearl millet plants.

In a study of emergence ability under field and greenhouse conditions at ICRISAT Center, results confirmed that emergence ability is genetically determined, which means that selection for improved emergence ability should be possible. Predicted genetic gains for emergence across selection intensities, by direct selection in the field, averaged 2.9% in the S_3 (3rd selfing) generation and 11.4% in the S_4 (4th generation). The predicted gains, under field conditions, based on correlated response to selection in the greenhouse, were about the same in the S_3 and approximately 20% of those for direct selection in the field in the S_4 generation. This research proves that direct selection under field conditions should be very effective over a few generation cycles in increasing the percentage of seedling emergence under stress.



Pearl millet seedlings emergence under stress; some emerge (right), *some do not* (left).



Striga hermonthica *in a farmer's sorghum field in Ethiopia.*

Changes in rainfall patterns in Sahelian Africa in the last two decades have increased the requirement for adaptation to drought stress during the flowering and grain-filling periods for new pearl millet varieties. This requirement is because of a generally shorter rainy season and the reduced rainfall in August. Results of experiments during the dry seasons of 1988 and 1989 at the ICRISAT Sahelian Center at Sadoré, Niger, indicated that both drought escape and drought tolerance contributed to better grain yields under flowering and grain-filling stress. Early-flowering entries which escaped drought had a greater grain mass because of longer grain-filling period. In Sahelian Africa, dramatic progress in their improving resistance to environmental stress should not be expected. Only a long-term concerted effort will achieve success in this difficult region.

Agronomic studies by ICRISAT scientists in southern Africa confirmed that nematodes in sandy soils contribute to poor establishment of sorghum. While seed treatment with carbofuran looked promising, growing pearl millet with greater tolerance for nematodes than sorghum in this region was seen as an alternate solution to the nematode problem.

Striga is a parasitic weed that reduces yield in sorghum in Asia and Africa. In laboratory experiments on germination of the seeds of *Striga asiatica* at ICRISAT Center, scientists found that the combination of high soil temperature (above 40°C) and 20-30% soil moisture was effective in killing the seeds in Vertisols (dark, clayey soils). These laboratory findings were confirmed in field conditions at both ICRISAT Center and in western Africa. The results indicate that the large reservoir of *Striga* seeds stored in the upper 100 mm of infested soils can be greatly reduced if fields are

kept moist for 2–3 weeks in the off-season when soil temperature is high (above 45°C). However, seeds buried deeper than this may escape the combined lethal effect.

ICRISAT scientists in Mali, were able to control *Striga hermonthica* in a heavily infested farmer's field through soil solarization. After irrigation, the *Striga*-infested plot was covered with a black polythene sheet for 35 days in one plot, and 15 days in another. The number of *Striga* plants in both plots was reduced when a local sorghum variety was grown later in either plot, and the reduction was greater in the plot that was covered longer.

The effect of molybdenum on nitrogen fixation in groundnut was studied at ICRISAT Sahelian Center. Nitrogenase activity and nodule dry mass were significantly increased by pelleting seed with molybdenum. Both seed pelleting with molybdenum at the rate of 100 g/ha and the application of fertilizer nitrogen (60 kg/ha) increased the total dry matter of the groundnut plant. However, the mean pod yield increased by 24% with seed pelleting with molybdenum, but by only 14% with nitrogen application. Groundnut genotypes from the SADCC/ICRISAT Groundnut Project (Malawi), ICRISAT Center, and western Africa were evaluated in five stressed environments at Sadoré, Niger, for their growth rates and the partitioning of nutrients to various parts of the plant. Several of the locally adapted early-maturing lines showed above-average partitioning of nutrients in the plant, particularly under stress. Cultivated groundnut variety 796 partitioned well under extreme stress, while another cultivated variety (55-437) partitioned very well under intermediate stress. ICGV 87123 showed good partitioning under all but the most extreme stress.

In collaboration with the Direction de la recherche agronomique in Benin, groundnut genotypes were compared for their response to humidity at Ina (Benin) and Sadoré (Niger). The dwarf line MH 2 did not compare favorably under stress with normal genotypes. ICRISAT scientists expect a dwarf stature to provide higher yield potential through high partitioning for groundnuts in humid regions of the world.

Differences in partitioning of nutrients between shoot and fruit in high humidity for contrasting groundnut genotypes at Ina, Benin.

Pigeonpea cyst nematode.

Strides towards Healthier Plants

Success in agricultural research fronts is often measured by the popularity of the released material among farmers. The success of ICRISAT pearl millet variety ICMV 1 (WC-C75), which in 1990 will be grown on over 1 million ha in India, is closely related to its high resistance to downy mildew (as mentioned earlier), a disease which devastated several earlier popular pearl millet varieties in the country. Fungi, bacteria, viruses, and nematodes constantly find ways to circumvent the plant's defenses. ICRISAT pathologists therefore perpetually strive to locate the best available defense mechanisms to help create the sturdy, high-yielding varieties or hybrids that can outwit nature's vagaries and thereby avoid food crises in the constrained regions of the semi-arid tropics.

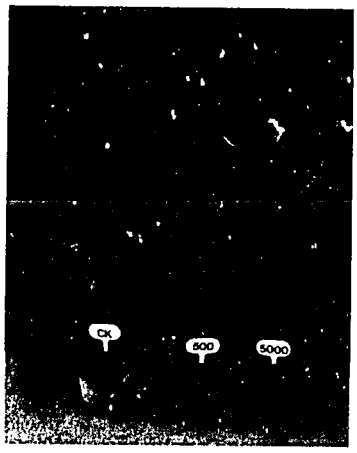
A research associate working on oospores at ICRISAT Center. Inset shows a germinating oospore of pearl millet downy mildew.

Infector rows (left) of sorghum downy mildew and test material growing at Golden Valley Research Station, Zambia, and (right) downy mildew in wild sorghum at Panmure, Zimbabwe.

Downy mildew continues to be a major disease of pearl millet, causing concern to scientists even after the success of ICMV 1 in India. ICRISAT pathologists, through the research of a doctoral student at Andhra Pradesh Agricultural University, were able to germinate downy mildew oospores (minute strong walled, unicellular reproductive bodies) in the laboratory. The method involves soaking oospores in water and later treating these soaked oospores with sodium hypochlorite. This procedure is followed by washing several times with sterile distilled water. The oospores are then resuspended in water maintained at a temperature of 28–30°C for germination. The method will facilitate effective studies on resistance mechanisms of the disease, and on the genetics of pathogen virulence. This laboratory success ensures that the longevity of the oospores can be studied and their role in the annual recurrence of the disease can be clarified.

A major achievement in 1989 was the successful introduction of sorghum downy mildew (*Peronosclerospora sorghi*) resistance into sorghum hybrids developed by ICRISAT scientists in southern Africa. In **Research Highlights 1988,** global differences among isolates of the pathogen of this disease were indicated. ICRISAT pathologists, in collaboration with the Zambian national program, confirmed that downy mildew of wild sorghum can initiate the infectious disease in cultivated sorghum. After 4 years of selection for local adaptation and downy-mildew resistance, over 70% of entries in the SADCC Advanced and Elite Hybrid Trials at Matopos, Zimbabwe, showed less than 5% mean incidence of the disease. In greenhouse studies on sorghum line QL 3 in Zimbabwe, artificially infected seedlings recovered, displaying high, though incomplete, resistance. This is an important breakthrough in controlling this major disease of sorghum in southern Africa.

Field screening in Zimbabwe for resistance to downy mildew among forage sorghum lines showed that 62% had less than 5% disease infection



The pigeonpea plant at far left is not affected by cyst nematode pathogenicity, while the others decrease in growth with increasing nematode numbers.

while among sweet-stalk sorghums, 21% had less than 5% disease incidence.

ICRISAT researchers in Mali working on gray leaf spot disease *(Cercospora sorghi)* found that in some sorghum genotypes the disease had little effect on grain mass under natural infection conditions. Results also showed that this reduction in grain mass could be further controlled by fungicide application.

Fusarium wilt *(Fusarium udum)* is a serious disease of pigeonpea in central and northern India, as well as in Kenya and Malawi. It is prevalent in India and has been reported in several other Asian and African countries. Ten years ago, yield loss in India from this disease was nearly 10 000 t, incurring a loss of U.S.$40 million in years of high infection. Basic studies on identification of physiologic races and inheritance of disease resistance need a rapid and reliable laboratory technique to inoculate pigeonpea with wilt.

ICRISAT scientists have adopted a laboratory root-dip inoculation technique to speed up such basic research efforts. This technique involves raising pigeonpea seedlings from seeds treated in 5% sodium hypochlorite (Clorox®) solution. The seedlings are then kept in polythene bags filled with sterilized sand. After 7–10 days, the seedlings are uprooted from the sand, their roots trimmed and dipped in a fusarium spore (a unicellular reproductive resting body) suspension, and then transplanted into pots containing a mixture of sand and Vertisol. These pots are kept in a greenhouse under controlled temperatures and irrigated with purified water. This technique proves that pigeonpea can withstand transplantation shock. Early-wilting, late-wilting, and resistant varieties can therefore be identified within 3 weeks. A range of inoculum levels and exposure periods to inoculum tested did not influence the reaction types.

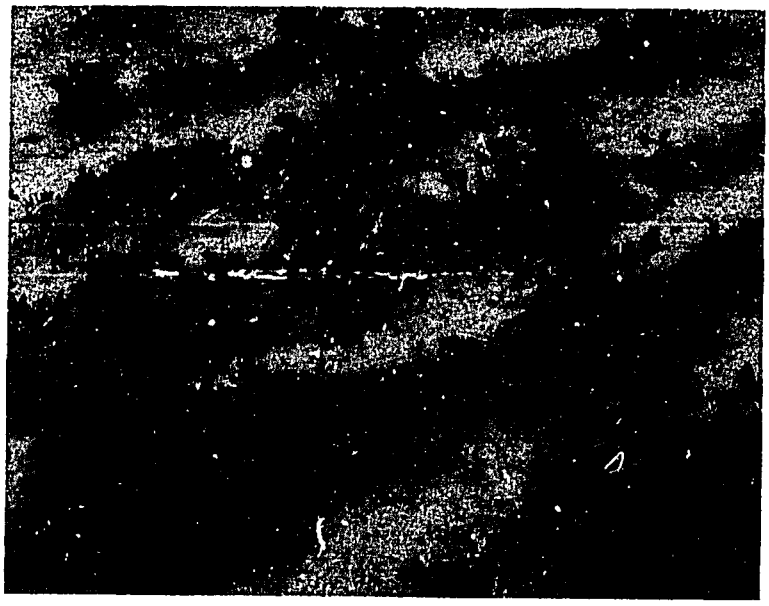
A diseased groundnut root (left) *and a healthy one* (right) *at Sadoré, ICRISAT Sahelian Center.*

ICRISAT nematologists standardized a greenhouse procedure to screen for the pigeonpea cyst nematode *(Heterodera cajani)* this year. The symptoms of infection by this nematode are not easily detected on pigeonpea foliage. Its presence can be identified only by a general reduction in plant growth. It also reduces seed yield by 30% . The screening method involves growing pigeonpea in nematode-infested soil and counting the number of white cysts (females) in the root system 30 days after seedling emergence. The roots are then partially air dried to remove surface moisture. The presence of white cysts produces a 'pearly root' symptom, characteristic of the infection. The procedure can also be used to screen other crops for susceptibility to the cyst nematode.

ICRISAT groundnut pathologists in western Africa tested groundnut crops at three locations in Niger for infection by *Aspergillus flavus* a fungus which results in aflatoxin contamination. They found that seed contamination depended on location. The cultivated varieties 55-437 and J 11 were the least contaminated at all locations, and the former yielded from 1.44 t/ha to 2.39 t/ha of groundnut seed.

The cause of the high degree of plant variability in western Africa was attributed to nematodes and peanut clump virus (PCV). At the ICRISAT Sahelian Center, while studying the host range of PCV, ICRISAT scientists found that this virus could infect plants other than groundnut. Enzyme-linked immunosorbant assay (ELISA) tests revealed the presence of the virus in three plant species belonging to the Gramineae family, three to the Leguminosae family, and one to the Pedaliaceae family. However, sunflower was found unaffected by the virus.

In studies conducted at the ICRISAT Sahelian Center on nematodes affecting groundnut crop growth, scientists found that populations of *Scutellonema clathricaudatum,* a nematode also found in Burkina Faso,



Variability in groundnut growth at Sadoré, ICRISAT Sahelian Center, Niger, has been attributed to nematodes and peanut clump virus.

Benin, and Nigeria, whose attacks reduce crop growth, do not migrate downwards significantly during the summer fallow period, but survive without water in the top 0-30 cm layer of the soil in the state of anhydrobiosis (or life away from water). At sowing, the greatest nematode population densities were found in the 0-15 cm soil layer. This information, it is hoped, will help to develop methods to control nematodes and prevent them from attacking succeeding groundnut crops.

ICRISAT cell biologists for several years have successfully incorporated resistances to late leaf spot and rust diseases of wild groundnuts into cultivated groundnut. In 1989, their attention was focused on two other groundnut diseases that cause yield losses in Africa—early leaf spot and the groundnut rosette virus. Wild species with resistance to these diseases were therefore identified by ICRISAT groundnut scientists working in Malawi. Unfortunately, these wild species are more difficult to cross with cultivated groundnut than the wild species resistant to rust and late leaf spot. Employing the ovule and embryo culture technique, many F_1 (first filial generation) hybrids have been raised in vitro and transferred to the screenhouse. These hybrids, some of which produced flowers and pods, exhibited resistance to the early leaf spot pathogen under laboratory conditions.

Transfer of disease resistance from wild groundnut species to other groundnut lines involves culturing hybrid tissues. Pictures alongside show the method used at ICRISAT Center. First the selected plant tissue is dissected (second from top). *Then the selected pieces are tranferred to a culture tube* (third from top) *and placed carefully on the surface of the medium* (fourth from top). *The tube is then sealed with a cotton plug* (bottom), *and then left to grow under controlled conditions.*

The Battle with Crop Pests

Midge resistant sorghum ICSV 743 being inspected by a farmer.

In the time a plant takes to complete one growth cycle, insects can complete 3-5 cycles. Insect pests devour plant parts below and above the ground, destroying the fruits of the farmers' labor. In this bleak scenario, farmers' fields become battlegrounds in which entomologists continuously devise new weapons to repel the invaders, while their insect adversaries adopt defenses at each attempt to defeat them. The scientist, in his role as the defender of the crops, can thus become the poor farmer's helpful ally.

For example, Indian farmers were pleased this year when the agronomically superior sorghum varieties ICSV 745 and ICSV 743, which are also resistant to midge *(Contarinia sorghicola)*, were adopted by the Department of Agriculture, Karnataka, for cultivation in midge-endemic areas. Information received by ICRISAT's collaborators at the University of Agricultural Sciences, Dharwad, Karnataka, indicates that ICSV 743 yielded 4.8 t/ha, and ICSV 745, 5.2 t/ha compared with the yield of the local hybrid (CSH 1) of 3.2 t/ha at Dharwad. The two ICRISAT varieties also outyielded the popular hybrids CSH 9 and A 101 in trials involving some 100 farmers in midge-endemic areas. This is good news for Indian farmers whose losses to midge and head bug *(Eurystylus immaculatus)* together amounts to U.S.$100 million a year. Comparitive data show that midge causes an annual loss of U.S.$9 million in Australia. In the USA, the insect causes 4% loss in sorghum yield, and in Nigeria and Ghana, 10-15%.

ICRISAT scientists, in collaboration with the Malian national program, have bred two improved sorghum varieties, CSM 388 and Malisor 84-7, selected from trials conducted since 1985 in Mali and Burkina Faso. Both varieties have resistance to head bug and are now being cultivated by farmers. Under high head-bug infestation at Samanko, Mali, CSM 388

The development of the midge-resistant sorghum ICSV 745 (second from right), *using resistance in ICSV 197* (second from left), *which was derived from the germplasm line DJ 6514* (far left). *At far right is the susceptible sorghum variety CSH 5.*

Sorghum variety CSM 388 has shown good resistance to head bug and is now cultivated by farmers in Mali. An ICRISAT entomologist (above) *examines a CSM 388 panicle.*

An ICRISAT entomologist (left) *explaining the head-cage screening technique to the Chief of Plant Protection in Mali.*

yielded 2.94 t/ha. ICRISAT scientists confirmed the resistance of these varieties to head bugs under artificial infestation using head cages. Studies in Nigeria revealed that head-bug infestation can reduce sorghum grain yield by 86%, grain size by 65%, and grain hardness by 45%.

Shoot fly *(Atherigona soccata)* causes over 23% actual loss in the gross income of sorghum farmers in India. Entomologists at ICRISAT Center demonstrated that the surface wetness of the central leaf in a shoot is a more important factor in shoot-fly resistance than high trichome density (the hair-like structure on the plant surface) or the glossy leaf trait. ICRISAT scientists studied the movement of the shoot-fly larvae and concluded that the role of the wetness of the central shoot leaf is very important for the insect.

Sugarcane aphid *(Melanaphis sacchari)*, another common pest of sorghum, causes considerable yield losses in Botswana and Zimbabwe. From 500 sorghum lines, ICRISAT scientists successfully identified 6 with high levels of resistance to aphids, and 7 with moderate levels. They established that resistance to this pest is controlled by a single dominant gene.

ICRISAT scientists in southern Africa continue their search for resistance in sorghum lines to the spotted stem borer *(Chilo partellus)*. After screening 1440 lines, 225 with low susceptibility were identified. Entomologists also established that significant yield losses occur when the spotted stem borer feeds on sorghum leaves.

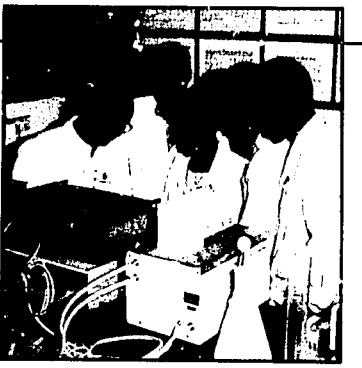
Eight sorghum lines were found significantly more resistant to the storage pest *Sitophilus* spp than local controls, Segaolare and Red Swazi.

Helicoverpa armigera causes 50-80% pod damage to the pigeonpea crop grown in southern India. Scientists at ICRISAT Center found, from several years' data, that severe outbreaks of *H. armigera* are associated with rainfall deficits. In experiments conducted at ICRISAT Center, physiological changes in drought-stressed chickpea were found to stimulate the feeding activity of *H. armigera* caterpillars. These findings suggest that soil-moisture conservation measures must be included in sound integrated pest management schemes.

ICRISAT physiologists have found a strong inverse relationship between aphid density and drought stress. The largest number of aphids were found on the plants least affected by drought stress.

ICRISAT entomologists discovered that the roots of some wild species of groundnut can resist the soil jewel beetle *Sphenoptera* sp (Buprestidae). This knowledge may be a key to identifying further resistance to groundnut root pests.

Insights on End Products: New Uses and Directions



Trainees learn to use a viscoamylograph at ICRISAT Center.

The ICRISAT mandate crops have to supply the nutritional requirements for humans and livestock. But in agricultural research, scientists seek traits in the grains of these crops that increase yield but do not attract rats, birds, and insects.

The resistance of sorghum to bird damage is crucial to the farmers who cultivate the crop. ICRISAT scientists in Zimbabwe noted that the tannin content of grains of four sorghum varieties diminished considerably between the soft dough and the maturity growth stages. Birds did not attack sorghum grains with low tannin content during the early-maturity stage.

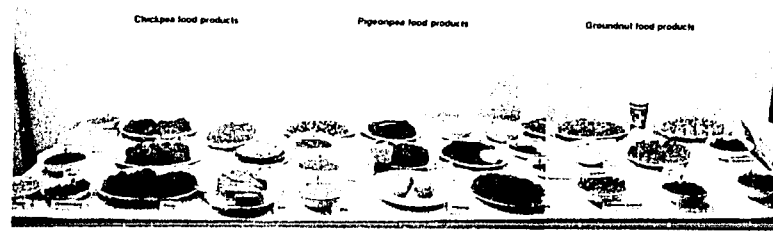
The consistency of starch paste under hot and cold conditions influences the texture of porridge and other starch products. Studies in 1989 showed that maize and sorghum starches are similar in swelling capacity, solubility, and viscosity. It therefore appears that sorghum can replace or supplement maize in industrial starch production.

Sorghum grain hardness also plays an important role in processing and food quality. The starch from hard-grained sorghum varieties has lower shear thinning (reduction in paste consistency after prolonged heating at 95°C) than soft-grained sorghums. Therefore, hard-grained sorghum is likely to help produce starch that can replace or supplement the starch extracted from maize.

The malting quality of sorghum and millet is important in brewing and food malt preparations. The ICRISAT food technologist in Zimbabwe standardized a laboratory micromalting system to evaluate the ability of sorghums and millets to convert starch into sugars. The methodology was tested on a control sorghum from ICRISAT Center with favorable results.

A sorghum field (left) *under attack by birds and* (right) *bird-damaged sorghum heads.*

Food products made from chickpea, pigeonpea, and groundnut.



Two sorghum accessions of the 10 dispatched to a prominent European brewery showed encouraging performance.

Of the 69 sweet-stalk sorghum accessions screened in Zimbabwe for sugar content and morphological traits such as plant height, 32 were selected for further testing in the lowland of southern Zimbabwe near a sugar factory. These selections showed brix values (a scale for sugar solutions) above 15% and sugar yields exceeding 4 t/ha.

Because chickpea leaves are consumed as a vegetable in many parts of India, ICRISAT biochemists assessed their nutritive value. They found that the protein and soluble sugar contents of chickpea leaves grown in irrigated and nonirrigated conditions were similar.

A stable starch viscosity on prolonged heating at high temperature is considered an important characteristic of mung bean starch used for noodle preparation. ICRISAT biochemists investigated this property using a viscoamylograph by heating the isolated starches of nine pigeonpea cultivated varieties at 95°C for 1 hour. The results indicated the stable viscosity of pigeonpea starch and hence its suitablity for noodle preparation. These varieties could substitute mung bean in this preparation.

Oxidative rancidity in groundnut oil can be measured by the oil's peroxide value. In oils with high concentrations of unsaturated fatty acids, oxidation is enhanced. The peroxide values of oil extracted from ICRISAT groundnut genotypes were below the maximum acceptable levels. A method to separate sugars using the gas chromatograph was standardized this year at ICRISAT Center.

Two meetings held during 1989 examined diversification of end products.

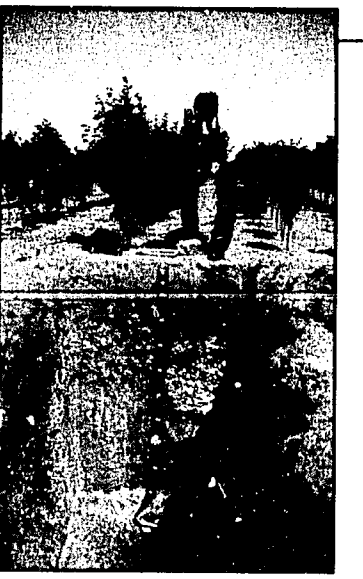
A consultants' meeting on uses of grain legumes held in March at ICRISAT Center emphasized the need to increase the range of products. Participants felt more information was required on biochemical and functional properties of grain legumes if these crops are to find wider acceptance.

The ban on the import of cereal grains and malt into Nigeria has given a new impetus to utilization of sorghum in that country. A national symposium was held jointly by the Institute for Agricultural Research and ICRISAT at Kano, Nigeria, in December, to analyze the current demand and supply of sorghum grain. A considerable shortage of sorghum grain was apparent. Industrial milling methods in Nigeria were also critically reviewed, prospects for using sorghum in the baking, brewing, and malting industries were evaluated, and the potential value of sorghum straw as forage and of sorghum grain in the feed industry was emphasized.

In November, a meeting of concerned individuals from government, parastatal, private, and research groups of Botswana, Zambia, and Zimbabwe met at Matopos, Zimbabwe, to focus on grain standards and their enforcement.

Better Utilization of Resources

Although mankind and domesticated animals have survived the harsh environment of the semi-arid tropics for centuries, recent population increases have led to the spread of cultivation into environmentally fragile areas. Survival depends on location-specific agricultural practices that create employment and increase crop production. ICRISAT, in its quest for sustainable agriculture, is concerned with the creation of a balance between human and livestock needs, and the preservation of the resources of the semi-arid environment.



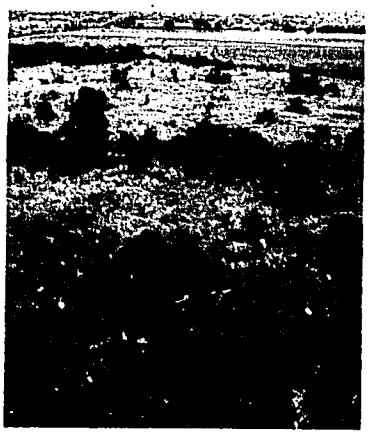
The roots of perennial pigeonpea penetrate deep into the soil (shallow Alfisol) enabling absorption of residual moisture.

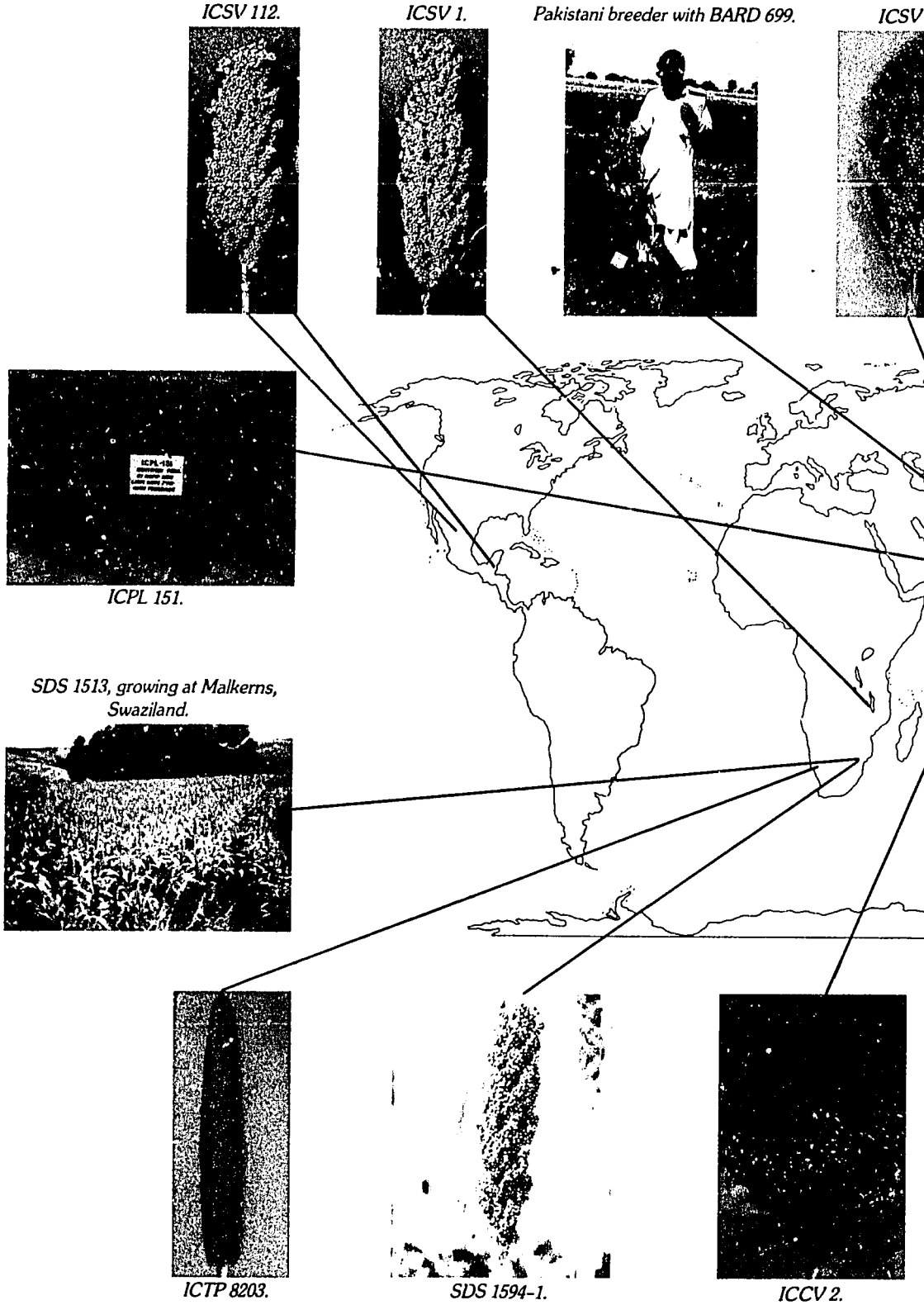
What to grow where

Livestock fodder is as difficult to obtain as food in some parts of the semi-arid tropics. Agroforesters at ICRISAT Center are therefore hard at work finding ways to produce fodder during the dry season (January to June) without compromising crop yields during the rainy season (June to October). They were successful in this area of research with perennial pigeonpea which does not require annual replanting.

(continued on page 28)

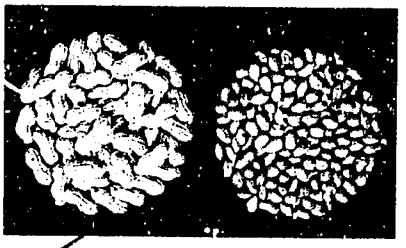
Growth of 1-year-old perennial pigeonpea on an Alfisol (left) *and the nearby natural vegetation area* (below) *fenced off from human intervention for 18 years at ICRISAT Center.*

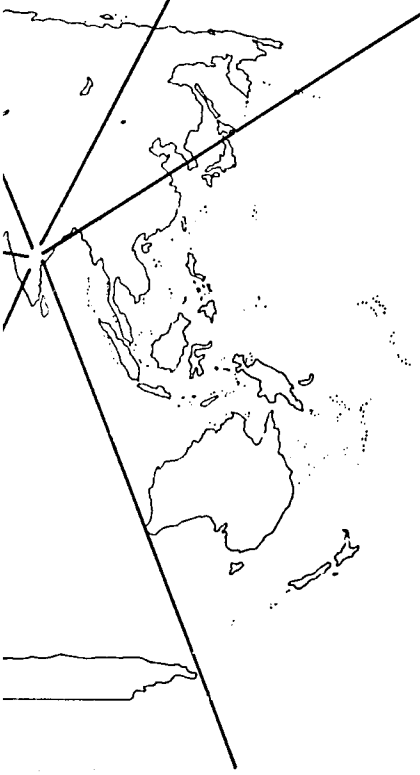



ICSV 112.
ICSV 1.
Pakistani breeder with BARD 699.
ICSV 7
ICPL 151.
SDS 1513, growing at Malkerns, Swaziland.
ICTP 8203.
SDS 1594-1.
ICCV 2.

ICSV 745.

ICGV 87141 (ICGS 76).





ICPL 332.

New Materials from ICRISAT that Reached Farmers in 1989

Crop	Material released	Region/country
Sorghum	ICSV 743	Karnataka, India
	ICSV 745	Karnataka, India
	SDS 1513	Swaziland
	SDS 1594-1	Swaziland
	ICSV 1	Malawi (as SPV 351)
	ICSV 112	Mexico (as Pacífico)
		Nicaragua (as Pinolero 1)
Pearl millet	ICTP 8203	Namibia (as Okashana 1)
	ICMV 82132	Zambia (as Kaufela)
Finger millet	SDFM 217 (IE 2929)	Zambia (as Lima)
Chickpea	ICCC 37	Andhra Pradesh, India (as Kranthi)
	ICCV 2	Andhra Pradesh, India (as Swetha)
	ILC 5566 (ICARDA)	Portugal (as Elmo)
	FLIP 85-17C (ICARDA)	Portugal (as Elvar)
	TS 1009 (ICARDA)	France
	TS 1502 (ICARDA)	France
	Janta 2 (ICARDA)	Lebanon
	ILC 237 (ICARDA)	Oman
Pigeonpea	ICPL 151	India (as Jagriti)
	ICPL 332	Andhra Pradesh, India (as Abhaya)
Groundnut	ICGS 76	Andhra Pradesh, Maharashtra, Tamil Nadu, and Karnataka, India
	ALR 1 (FESR selection)	India (earlier released in Tamil Nadu only)
	BARD 699 (composite of ICGV 87128 and ICGV 87187)	Pakistan
	Jinpungtangkong (selection from ICGV 87127)	Republic of Korea

(continued from page 25)

Research scholar from UK measuring photosynthesis of perennial pigeonpea at ICRISAT Center.

In addition to its useful contribution to domestic diets, its leaves are readily acceptable as livestock fodder. As a woody plant also it provides quick returns in the form of fuelwood and building material, and it fixes nitrogen in the soil. It thus makes a positive contribution to soil fertility and sustainable crop production.

Perennial pigeonpea is suitable for sowing in intercropped rows with other crops particularly cereals, under good-rainfall conditions. If sown in the rainy season, it matures slowly but its roots penetrate deeply, enabling absorption of the residual soil moisture in the following dry season. Experiments at ICRISAT Center proved that low plant density helps perennial pigeonpea become more productive than when sown at high density.

ICRISAT scientists identified lines with promise in agroforestry systems. These lines combine disease resistance with excellent agronomic traits in both erect and spreading types. These pigeonpea lines had the ability to achieve high grain yield when competing with a more dominant species, such as sorghum. When the plants are pruned at 0.5 m, they regrow. While pigeonpea seeds are consumed as *dhal* (grain in its dry split form) in India, they are consumed as green peas in eastern Africa, the Caribbean, and some parts of India. Even its harvest trash—pod walls, leaves, and stems—have good animal feed value and can be mixed with low-quality forage to improve livestock diets. After harvest, the main stems are used as fuelwood and thin straight branches for thatching and basket-weaving.

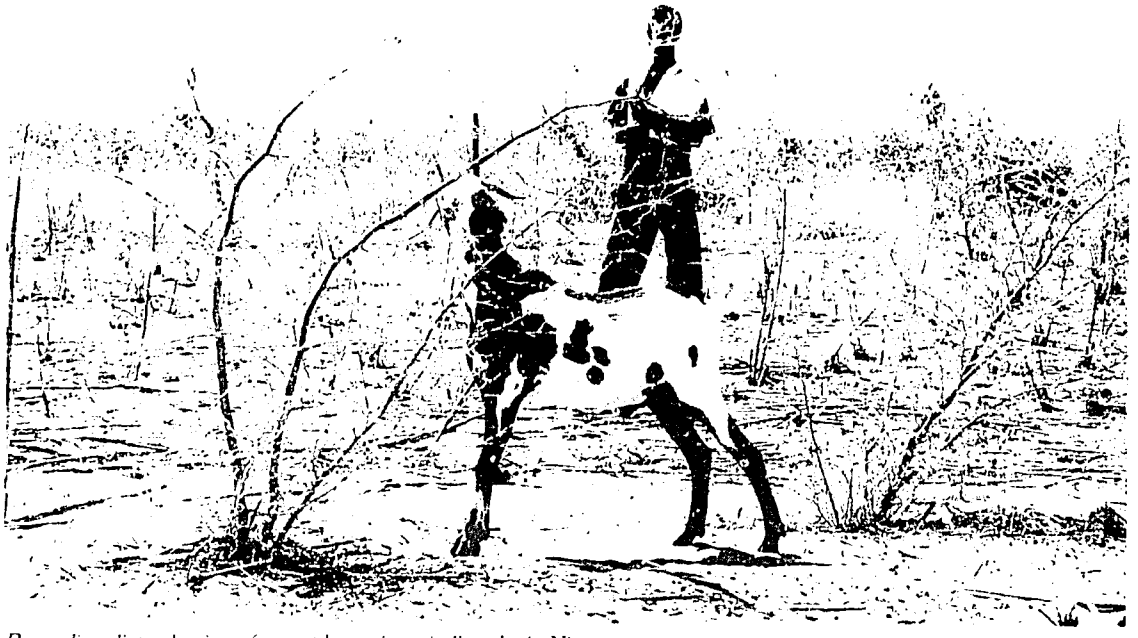
Pruned cuttings from the pigeonpea crop are available throughout the year and their maximum benefit as a green manure can be achieved if they are worked into the soil. In addition to the leaf litter, root residue from a 2-year-old perennial pigeonpea crop increased the yields of a succeeding maize crop by 1 t/ha. These beneficial effects were found to last beyond the succeeding cereal crop.

Andropogon gayanus, *a perennial native grass, is proving useful in Niger for its crop-protective qualities.*

In a collaborative project with ICRISAT, studies by the Ministry of Agriculture in Thailand and the Australian Centre for International Agricultural Research (ACIAR) have suggested that pigeonpea can be profitably grown in northeast Thailand and could possibly replace imported soybean in chicken broiler diets.

ICRISAT economists, together with ACIAR and Thai scientists, studied meteorological data, maps of land-use potential, and results of on-farm experiments conducted by Thai scientists on pigeonpea in northeastern provinces of Thailand. They concluded that though pigeonpea is not currently grown in northeast Thailand, in the forseeable future it could replace locally grown kenaf or cassava. But ICRISAT economists cautioned that interest in growing pigeonpea would decrease if it diminished rice production, if pigeonpea yields were less than 1 t/ha, if effective and low-cost pest management was not available, or if the government stimulated increases in domestic soybean production.

In farming systems studies in Niger, another plant, *Andropogon gayanus*, a perennial native grass, is proving useful for its crop-protective qualities. This plant, grown in strips around pearl millet plots, significantly reduced wind speed, trapping the wind-blown sand which can destroy the pearl millet seedlings by abrading or by burying them under blown sand. Strips of *Andropogon* planted in 1986 to protect pearl millet plots trapped a total of 2.2 t/ha of sand in 3 years. As the straw of *Andropogon* has good



Recording diet selection of a goat browsing windbreaks in Niger.

stover value, the combined income from pearl millet seed and stover plus *Andropogon* stover could make this system economically attractive.

Studies in collaboration with the International Institute of Tropical Agriculture on cowpea, a legume of increasing importance to the harsh environment of the hot, sandy Sahel, showed that cultivated Sahelian varieties and lines derived from them are more heat tolerant than cultivated varieties introduced into the region. This conclusion was reached after studying the abilities of 13 cowpea lines to produce flowers and pods under very high temperatures during the hottest months (March and April) of the dry season.

Scientists tested various legumes at the ICRISAT Sahelian Center (ISC) and found guar *(Cyamopsis tetragonolobus)* promising and recommended that further research be conducted on the crop for possible cultivation in the Sahel.

ISC agroforesters, in collaboration with a nutritionist from the International Livestock Centre for Africa, conducted a study on six browse species for sheep and goats. The animals found two species *(Bouhinia rufesceus* and *Ziziphus mauritania)* as palatable as cowpea hay.

ISC agroforesters studying *Faidherbia albida* confirmed that genotypes originating from the Sahel were able to survive the Sahelian semi-arid conditions better than genotypes originating from southern Africa, even though the southern African genotypes were found superior elsewhere. The ICRISAT scientists attribute the high mortality rate of southern African genotypes in the Sahel to their lower root biomass compared with that of western African genotypes.

Studying rooting pattern of Faidherbia albida, *at Sadoré, ICRISAT Sahelian Center, Niger.*

Better cropping systems

ICRISAT scientists confirmed in trials at Sadoré (Sahelian zone) and at Tara (Sudanian zone) that rotating pearl millet with legumes such as cowpea or groundnut is beneficial. In both zones, pearl millet sown in a field in which cowpea had been previously grown gave increased (58%–100%) yields compared with the yield of millet grown immediately after another millet crop.

At ICRISAT Center, scientists had previously demonstrated that yields of a sorghum crop grown without fertilizer nitrogen could be increased from 1.1 t/ha to 2.7 t/ha by rotating sorghum with pigeonpea instead of sowing it continuously on the same plot, while the addition of fertilizer only increased the yield to 3.4 t/ha. Experiments showed that sorghum benefited from a preceding pigeonpea crop and pearl millet from a preceding groundnut crop. However, the benefits of nitrogen nutrition to the soil from a legume crop diminished when there was excess rainfall, which probably lead to considerable leaching (a process whereby the passage of water through soil removes soluble material) of nitrates beyond the root zone.

In a comparative study on castor and a legume crop, in collaboration with the Central Research Institute for Dryland Agriculture, Hyderabad, India, pearl millet yields were significantly greater than castor. ICRISAT scientists attributed the difference to pearl millet's faster-growing root system that assimilates nitrate faster (thus minimizing leaching losses) than the slower-growing and less-extensive castor root system. The studies revealed that on Alfisols (red, light-textured soils), soil texture and the type of beneficiary crop were important features determining optimal cropping systems. It is evident from these experiments that availability of nitrogen to cereals on Alfisols is enhanced by a preceding legume crop, but management of the soil is complex compared with that of Vertisols (dark, clayey soils) on which preceding legumes consistently improved such following cereal crops as sorghum.

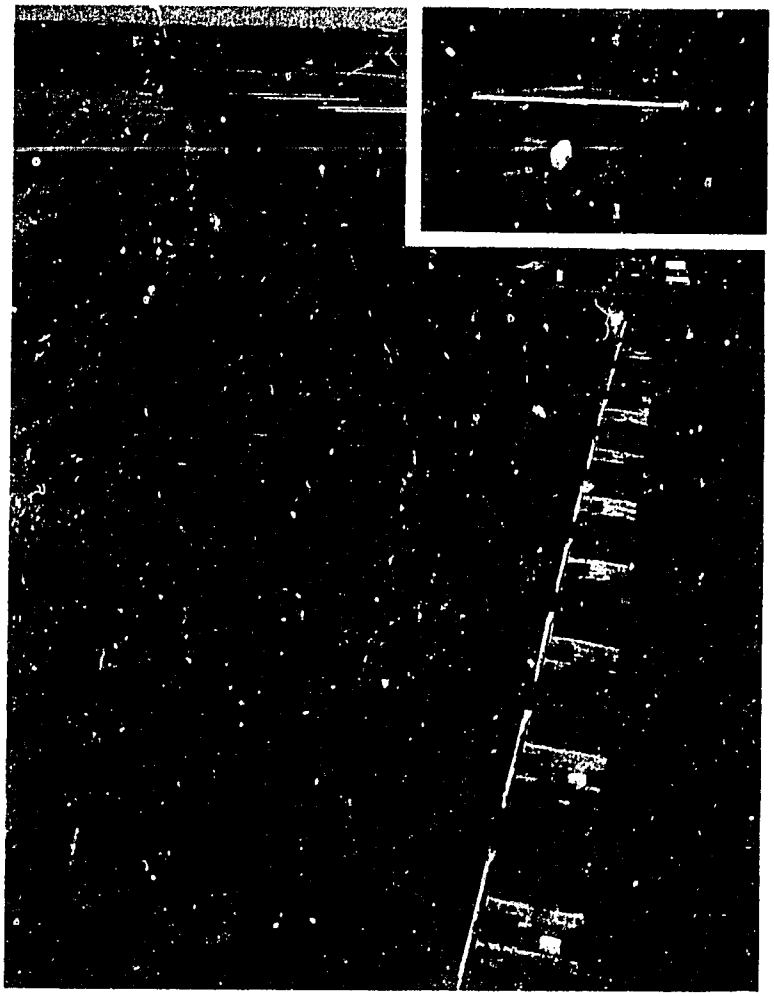
Studying the soil

Yield increases on Alfisols can be achieved by normal tillage, application of organic manure, and increasing water retention, but intensive tillage, which is often recommended, is not the answer.

Tillage and alternative systems of soil management were considered by ICRISAT scientists. Organic amendments were added to the soil to protect the soil surface and to encourage biological activity in the soil. Perennial crops were then sown to provide surface protection and dry-matter production. Rice straw used as a cover effectively reduced runoff of rain water on Alfisols for a year, even after the straw had decomposed.

The climate factor

In western Africa, a succession of dry years has contributed to the degradation of the environment. A comparison of parameters such as total rainfall, number of rainy days, amount of rain per day, and the average interval between rainy days for two periods in Niger showed that rains



*Soil-management studies at ICRISAT Center on Alfisols: perennial pigeonpea growing on plots with runoff water recording devices (*inset: *close-up of devices).*

became less frequent after 1985, and that the volume of rain in each storm also decreased. The persistence of low rainfall is a threat to sustainable agriculture.

The yield of such crops as pearl millet is severely reduced when drought stress persists for 10-20 days after flowering. However, stress occurring before or at the flowering stage does not appreciably decrease yields.

This year, ICRISAT agroclimatologists developed a simple model based on principles of resource capture. The model simulates the growth and yield of both cereals and legumes in response to weather. It can predict biomass, seed yield, and daily water use in response to weather, soil water availability, and supplemental irrigation.

In a study on the effects of weather on groundnut foliar diseases, ICRISAT scientists found that periods of wetness at night are necessary for the rust disease pathogen to infect the crop. The rust infection process is inhibited by light. Studies at ICRISAT Center revealed that wetness from dew, or rain late in the day, may linger for about 12 hours. Substantial infection was likely only if the period of wetness was longer than 8 hours.

Rust infection was most likely when the night temperature was about 25°C, but below 15°C, much less infection occurred. These findings will help to identify periods when weather favors rapid disease development and could provide the basis for a scheme to optimize the timing of control measures.

Towards better monetary returns

In **Research Highlights 1988**, the combination of crops, the use of animal traction, application of phosphorus, and cropping systems developed by the operational scale research (OPSCAR) trials at ICRISAT Sahelian Center were discussed. Data from experiments conducted between 1986 and 1988 were analyzed. This analysis showed that manual cultivation of millet and cowpea in rotation, or as intercrops, together with the application of phosphatic fertilizer, may be the best package to recommend to the farmers of Sahelian Africa.

However, the analysis also showed improved returns on land and household labor can be obtained when animal traction is used if the land owned by the farmer was over 4 to 5 ha.

The study revealed that the choice between intercropping and rotation depends on household labor and resources. A cowpea-pearl millet rotation was favored by farmers because managing sowing dates and densities was more convenient than the intercrop option.

ICRISAT economists in southern Africa found that sorghum and millets could compete well with crops such as maize for use in industry given increased production, lower marketing costs, and a pricing policy based on demand.

Farmers visiting OPSCAR trials at Birni N'Konni, Niger.

Transfer of Technology

ICRISAT is committed to the development and transfer of technology to farmers through cooperation with national and regional research programs. In 1989, ICRISAT emphasized this objective of its mandate by human resources development, sponsoring workshops, building networks of cooperation, and assisting in extension activities.

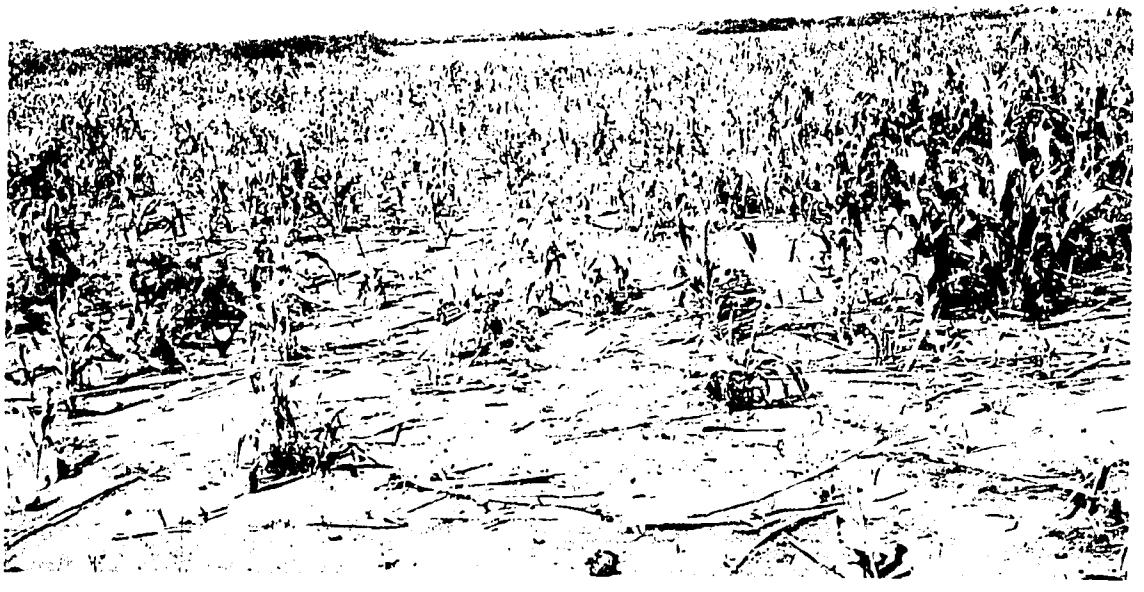
Participants of the Peanut Stripe Virus Coordinators' meeting examine groundnuts during a tour of ICRISAT Center.

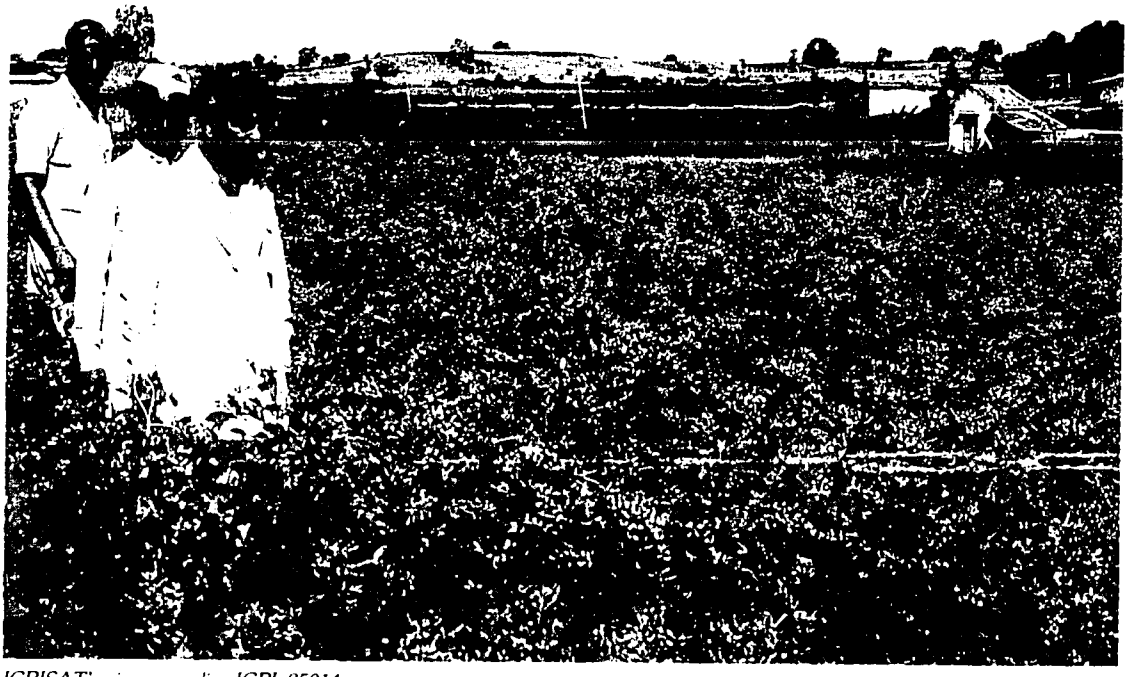
Improved impact of ICRISAT research

In Mali, ICRISAT staff, in collaboration with the Institut d'économie rurale, tested in farmers' fields an improved intercropping system in which millet and maize are grown in alternate rows in the same field. They found a consistent increase of about 40% in total grain yield using this intercropping system over that of the component crops grown in monoculture, and substantially higher grain yield than that achieved in traditional millet/maize systems. This system has been widely adopted by farmers on over 20 000 ha in the cotton-growing zone.

The recommended cereal/cowpea intercropping system has shown increases of 30% more than monocrops. On-farm trials have confirmed these results and the cereal/cowpea intercropping system is being adopted by farmers in zones where the rural development agencies have promoted it.

Sorghum attacked by stem borers in a farmers' field in Somalia. Sorghum stalks from the previous season are left lying in the field.





ICRISAT's pigeonpea line ICPL 85014 growing in a Maharashtra Department of Agriculture trial, assisted by ICRISAT's LEGOFTEN Unit.

ICRISAT sorghums were well received in western Africa in 1989. In Burkina Faso, 3 t of seed of ICRISAT sorghum variety ICSV 1049 BF were produced. In Ghana, several tonnes of seed of the sorghum variety Framida were given by extension services to farmers. In Togo, 15 t of Framida seed were produced, and 250 kg in Côte d'Ivoire.

In Chad, an estimated 30 000 ha were sown to ICRISAT pearl millet variety ITMV 8001 during 1989.

In India, two hybrids developed by public-sector seed companies and another by a private company are widely grown. They are based on ICRISAT's ICMA 841A, a downy-mildew resistant seed parent. Similarly, ICRISAT's sorghum male-sterile lines 81A and 834A have been used to breed several other sorghum hybrids promoted by the private sector.

In Zimbabwe, dairy farmers began to grow hybrids, derived from pearl millet and napier grass crosses. They were developed by the ICRISAT scientists based in Zimbabwe.

Stem borer *(Chilo partellus)* is a serious pest of sorghum in Somalia, especially if the crop is ratooned. In response to a request from the Somalian national program, ICRISAT assisted in the establishment of a stem-borer rearing facility at Bonka Dryland Agricultural Research Station, and in training national program staff in screening for and evaluation of stem-borer resistance.

In India, government promotion programs for the growing of oilseeds, assisted by the work of ICRISAT's Legumes On-farm Testing and Nursery (LEGOFTEN) Unit, have kindled interest among farmers in growing groundnut. ICRISAT's technology transfer activities in groundnut-growing areas led to the adoption of improved methods on more than 70 000 ha in

Short-duration pigeonpea growing at a farm at Baroda, Gujarat, India, in a Gujarat Department of Agriculture trial, assisted by ICRISAT's LEGOFTEN Unit.

Maharashtra and Karnataka in the 1988/89 postrainy *(rabi)* season. Government agencies and private farmers multiplied the seed of ICRISAT's improved varieties and helped to distribute them. The National Dairy Development Board is making an effort to adopt the improved technology on a large scale in seven states—Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Orissa, and Tamil Nadu. In Madhya Pradesh, as a result of the LEGOFTEN-assisted State Department of Agriculture trials, farmers have expressed interest in growing groundnuts in areas where soybean has been the main oilseed crop.

These programs, which this year were extended to include chickpea and pigeonpea, have increased the popularity of extra-short-duration chickpeas in several Indian states. In Parbhani district of Maharashtra state, the area under ICRISAT chickpea variety ICCV 2 increased from less than 1 ha in the 1988/89 postrainy season to over 30 ha in the 1989/90 season, while the quantity of seed of this variety multiplied by farmers increased from 2 to 45 t. In these programs, ICCV 2 gave 30% more yield than long-duration varieties under residual moisture conditions. The seed of this variety remains in great demand.

In these programs, yields of extra-short-duration pigeonpea genotypes under postrainy summer conditions ranged from 0.6 to 1.0 t/ha in Tamil Nadu, from 0.6 to 1.3 t/ha in Maharashtra, and from 0.08 to 0.52 t/ha in Karnataka. Average yields were 0.74 t/ha in Andhra Pradesh and 0.80 t/ha in Gujarat.

The trials have increased the popularity of ICRISAT's short-duration pigeonpea variety ICPL 87 released in India in 1986 as Pragati. In 1989, ICPL 87 was grown on about 10 000 ha in Maharashtra and 4 000 ha in

Madhya Pradesh. Noting that the demand for ICPL 87 was increasing, a prominent private-sector company, ITC Ltd, began marketing it. ICRISAT hybrid pigeonpeas are popular with MAHYCO, another private seed company headquartered in Maharashtra, where the company marketed a hybrid based on ICRISAT material in nine districts.

Improving collaborative networks

ICRISAT signed a Memorandum of Understanding with the Ministry of Agriculture and Food Industry of Vietnam. This document provides the framework to strengthen ICRISAT's Asian Grain Legumes Network (AGLN) activities. Eleven countries in South and Southeast Asia will now participate in this network.

In support of agreements with the People's Republic of China, ICRISAT drew up a workplan of collaborative AGLN activities in that country.

Existing workplans were reviewed with the national programs of Bangladesh, Myanmar, Nepal, and Sri Lanka. AGLN activities in these countries are aided by the Asian Development Bank. An ICRISAT chickpea breeder was stationed in Nepal to assist in the selection, evaluation, and harvesting of breeding material. Scientists from Nepal spent several fruitful months at ICRISAT Center to learn methods to improve their legume production. A similar exchange of visits took place between ICRISAT scientists and national program scientists, from Bangladesh, Myanmar, and Sri Lanka.

Two ICRISAT scientists (far left and far right) *with Chinese national program scientists examining groundnuts in the People's Republic of China.*

In collaboration with the ACIAR, workplans were prepared for research on pigeonpea in Thailand and Indonesia, and on groundnut in Indonesia. In cooperation with the Philippines Council of Agricultural Research and Resource Development, workplans were also drawn up for research on several grain legumes in that country.

Since the initiation of the Cereals Cooperative Research Network in 1986, ICRISAT-bred sorghum varieties have been adopted by national agricultural research systems in Ecuador, El Salvador, Malawi, and Zimbabwe, while breeding lines developed at ICRISAT Center and by regional programs have been used in breeding programs in the People's Republic of China.

The West and Central African Millet Research Network was formally created at the Regional Pearl Millet Workshop held at ICRISAT Sahelian Center in 1989. This network is expected to improve regional cooperation in pearl millet cultivation.

Events that promoted technology transfer

A 6-day monitoring tour of chickpea and pigeonpea fields in the Terai region of Nepal and the 4-day workshop on legume improvement that followed at Kathmandu provided the first opportunity for representatives of 10 AGLN countries to meet in March 1989. (Vietnam, the 11th member, was then not a member of the network.) In another AGLN event cospon-

An ICRISAT scientist (far right) *discusses pigeonpea research with Burmese and Thai scientists during a monitoring tour of farmers' fields in Nepal.*

An ICRISAT scientist (left) *examines a pigeonpea plant with a Sri Lankan scientist at Girandurakotte, Sri Lanka.*

sored by the Bangladesh Agricultural Research Institute and the International Development Research Centre (Canada), ICRISAT organized a national workshop on pulses in June at Joydebpur, Bangladesh.

In December, the second International Workshop on Chickpea Improvement was held at ICRISAT Center. Called 'Chickpea in the Nineties', this workshop was jointly organized by ICARDA and ICRISAT. Participants discussed the future prospects and research goals of the crop. One hundred and forty-two delegates from 29 countries discussed the approaches needed to bring about sustained and substantial increases in global chickpea production.

At another international meeting, 39 plant virologists from 11 countries gathered at ICRISAT Center to discuss research on peanut stripe virus, the most economically damaging virus of groundnut in South and Southeast Asia. This virus is estimated to cause crop losses worth millions of U.S. dollars annually in the People's Republic of China, Indonesia, and the Philippines. It has the potential to cause severe yield losses in India, where it was detected in 1987. It has subsequently been identified at several research locations. Measures to minimize the risk of virus spread and efforts to locate resistance to it were discussed.

In southern Africa, a traveling workshop on livestock forage was held early in the year by the ICRISAT's sorghum and millets scientists working in Zimbabwe. Sixteen scientists from six southern African countries and

from regional programs visited forage research sites in Zimbabwe, Botswana, Lesotho, Mozambique, and Swaziland.

If research on farms is important, so is the role of experiment station development and management. ICRISAT conducted the First Regional Workshop on Experiment Station Development and Management at Matopos, Zimbabwe, to develop a regional strategy to strengthen and sustain this activity in the SADCC region.

The West and Central African Sorghum Research Network (WCASRN) organized a research monitoring tour in October for seven scientists from Benin, Burkina Faso, Cameroon, Chad, Guinea, Mali, and Togo. These visits to trials and nurseries in Mali, Burkina Faso, and Niger gave the touring scientists an opportunity to evaluate and select breeding materials for use in their respective programs.

Human resource development

The fruits of agricultural research at institutions such as ICRISAT will be of little use if scientists, technicians, and students do not apply these findings effectively in their own countries. This year 208 men and 50 women, nominated for training by governments, universities, or national agricultu-

African national scientists (foreground) *learning soil and plant analysis at an ICRISAT Center laboratory.*

In-service trainees evaluating plant stand at ICRISAT Center.

ral research organizations, participated in skill development activities at ICRISAT Center.

Eighty-four nominees from 30 countries took part in rainy-season practical field training, conducting some 200 experiments and international trials at ICRISAT Center.

In efforts to improve staff skills, the human resource development program conducted by ICRISAT and INTSORMIL (USAID Title XII Collaborative Research Support Program on Sorghum and Pearl Millet) in Zimbabwe strengthened research capabilities of national agricultural research systems of SADCC countries by providing courses and facilities to 104 technicians and students.

To keep up with the rising popularity of sorghum hybrids in Nigeria, 10 national participants benefited from a practical training course in hybrid sorghum seed production conducted by ICRISAT sorghum scientists at Bagauda, Nigeria. Finally, WCASRN conducted a training workshop on agronomic research and on-farm testing in Mali for nine participants from nine countries in western and central Africa.

ICRISAT
Governing Board—1989

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Secretary to the Government of India
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Mr C. Srinivasa Sastry
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Krishi Bhavan
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Mr G.R. Nair
Chief Secretary to the
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Faculty of Agriculture
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Presidente
Colegio de Ingenieros Agronomos
de Mexico, A.C.
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Chief Agricultural Research Officer
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Dr R.H. Smith (from April)
Professor of Plant Physiology
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ICRISAT Senior Staff— as of 31 Dec 1989

ICRISAT Center

Administration

L.D. Swindale, Director General
Y.L. Nene, Deputy Director General (from Apr)
M. Goon, Assistant Director General (Administration)
K.B. Srinivasan, Assistant Director General (Liaison) (until May)
B.C.G. Gunasekera, Advisor to Director General for Donor Relations
B.K. Patel, Special Assistant to Director General for Planning (from Jun)
P. Reavey, Special Assistant to Director General for Educational Affairs
V. Balasubramanian, Sr Executive Officer (Director General's Office)
J. Gay, Sr Adm Secretary to DG
P. Rama Murthy, Adm Officer, Office of Advisor to DG (DR)
P. Subrahmanyam, Sr Adm Officer, Office of the DDG (until Apr)
G.J. Michael, Adm Officer, Office of the DDG (from Apr)
Sheila Vijayakumar, Sr Research Associate, Office of the DDG (from Jun)
K. Sampath Kumar, Adm Secretary, Office of the DDG (until Apr)
S. Krishnan, Asst Manager (Admn) Admn Services (Delhi Office, from Dec)
C. Geetha, Adm Secretary, Office of the ADG (Admn)
P. Sosamma Nair, Adm Officer, Office of the ADG (Liaison)
D. Mitra, Fiscal Manager
A. Banerji, Assistant Manager (Fiscal) (on special leave)
C.P. Rajagopalan, Accounts Officer
P.A.V.N. Kumud Nath, Accounts Officer
K. Narayana Murthy, Accounts Officer
B.K. Vasu, Accounts Officer
T. Kulashekhar, Accounts Officer
T.K. Srinivasan, Accounts Officer
N.V.V. Rao, Accounts Officer
P.M. Menon, Personnel Manager (Acting)
K.K. Vij, Asst Manager (Admn) (from Dec)
N.S.L. Kumar, Sr Personnel Officer
P. Suryanarayana, Sr Personnel Officer
A.J. Rama Rao, Adm Secretary (Personnel)
R. Vaidyanathan, Purchase and Stores Manager
C.R. Krishnan, Asst Manager (Purchase and Stores)
K.P. Nair, Sr Purchase Officer (on leave from Feb)
D.K. Mehta, Sr Stores Officer
D.V. Rama Raju, Sr Purchase Officer
K.C. Saxena, Sr Stores Officer
K.R. Natarajan, Shipping and Purchase Officer
J. Banji, Purchase Officer
T. Gopalakrishnan, Purchase Officer
A. Lakshminarayana, Sr Scientific Liaison Officer (Visitors' Services)
Harish Sethi, Scientific Liaison Officer
G. Fredericks, Adm Officer (Visitors' Services)
K.K. Sood, Sr Security Officer
K.K. Vij, Asst Manager (Admn) (Delhi Office until Dec)
K. Santhanam, Manager (Internal Audit) (on contract)
V. Satish Kumar, Audit Officer
N. Surya Prakash Rao, Sr Resident Medical Officer
K. Jagannadham, Transport Officer
A. Rama Murthy, Travel Officer
V.V. Ramana Rao, Adm Officer

Research Programs

Cereals

Program Office

J.M.J. de Wet, Program Director, Cereals
V.S. Swaminathan, Sr Adm Officer (until Apr)
N.V.N. Chari, Adm Officer (from Apr)

Sorghum Group

J.W. Stenhouse, Principal Plant Breeder (from Nov)
L.K. Mughogho, Principal Plant Pathologist
J.M. Peacock, Principal Plant Physiologist
K.F. Nwanze, Principal Cereals Entomologist
C.M. Pattanayak, Principal Coordinator CCRN
G. Alagarswamy, Plant Physiologist
B.L. Agrawal, Plant Breeder (on leave from Aug)
Belum V.S. Reddy, Plant Breeder
P.K. Vaidya, Plant Breeder
N. Seetharama, Sr Plant Physiologist
P. Soman, Plant Physiologist
Suresh Pande, Plant Pathologist
R. Bandyopadhyay, Plant Pathologist
S.L. Taneja, Entomologist
H.C. Sharma, Entomologist
H.D. Patil, Sr Research Associate (until Nov)
K. David Nicodemus, Sr Research Associate
P.S. Raju, Sr Research Associate (until Apr)
V.L. Chidley, Sr Research Associate
M. Peterschmitt, Postdoctoral Fellow
C.S. Busso, Postdoctoral Fellow
H. Kokubu, Postdoctoral Fellow (until Feb)
M.A. Osman, Postdoctoral Fellow
F. Pinard, Postdoctoral Fellow (from Sep)
S.D.K. Trichur, Research Scholar (until Apr)
K.G. Kausalya, Research Scholar
Mohd Hassan Aden, Research Scholar
Hassan A. Hassan, Research Scholar (until Feb)
S.S. Poranki, Research Scholar (from Jun)
A.P.P. Kumari, Research Scholar (from Aug)
G. Ravi Kumar, Research Scholar (from Oct)
Mahad Abdi Farah, Research Scholar (from Oct)
S. Sithole, Research Scholar (until Oct)

Pearl Millet Group

F.R. Bidinger, Principal Plant Physiologist
S.B. King, Principal Plant Pathologist (on study leave from Jun)
J.R. Witcombe, Principal Plant Breeder
K.N. Rai, Plant Breeder

B.S. Talukdar, Plant Breeder
S.B. Chavan, Plant Breeder (until Oct)
V. Mahalakshmi, Plant Physiologist
S.D. Singh, Sr Plant Pathologist
R.P. Thakur, Sr Plant Pathologist
K.R. Krishna, Microbiologist (until Oct)
B.P. Reddy, Sr Research Associate
E. Weltzien, Postdoctoral Fellow (until Nov)
P.J. Lynch, Research Scholar (from Jun)

Kenya

V.Y. Guiragossian, SAFGRAD/ICRISAT Coordinator for Sorghum and Millet, Eastern Africa
S.Z. Mukuru, Principal Sorghum Breeder

Mexico

C.L. Paul, Team Leader and Principal Sorghum Agronomist (on sabbatical until Oct)
C.T. Hash, Principal Sorghum Breeder
R. Clara Valencia, Scientist, Sorghum Breeder

Legumes

Program Office

Y.L. Nene, Program Director, Legumes (until Mar)
D. McDonald, Program Director (Acting, from Mar)
D.G. Faris, Principal Coordinator, Asian Grain Legumes Network
C.L.L. Gowda, Sr Legumes Breeder, AGLN
D.M. Pawar, Sr Agricultural Officer (Cooperative Trials, LEGOFTEN)
Sheila Vijayakumar, Sr Research Associate (until Jun)
G.J. Michael, Adm Officer (until Apr)
K. Sampath Kumar, Adm Officer (from Apr)

Pulses Group

C. Johansen, Principal Crop Physiologist
H.A. van Rheenen, Principal Plant Breeder, Chickpea
Laxman Singh, Principal Plant Breeder, Pigeonpea (until Aug)
M.P. Pimbert, Principal Entomologist
J. Arihara, Associate Principal Physiologist (until Nov)
N. Ae, Associate Principal Microbiologist (until Nov)
K. Okada, Asst Principal Microbiologist
K.C. Jain, Plant Breeder, Pigeonpea
Onkar Singh, Plant Breeder, Chickpea
M.P. Srivastava, Sr Plant Breeder (on contract until Jun)
K.B. Saxena, Sr Plant Breeder, Pigeonpea
V.K. Sehgal, Sr Scientist (Entomology) (on contract until Feb)
S.S. Lateef, Entomologist
M.P. Haware, Plant Pathologist
S.C. Sethi, Plant Breeder, Chickpea
N.P. Saxena, Sr Crop Physiologist
O.P. Rupela, Crop Physiologist
K.R. Krishna, Crop Physiologist (from Oct)
J.V.D.K. Kumar Rao, Crop Physiologist, LEGOFTEN
C.S. Pawar, Entomologist, LEGOFTEN
A.M. Ghanekar, Plant Pathologist
Jagdish Kumar, Plant Breeder, Chickpea
S.C. Gupta, Plant Breeder, Pigeonpea
M.V. Reddy, Sr Plant Pathologist
Y.S. Chauhan, Crop Physiologist
S.B. Sharma, Plant Nematologist
N.V. Ratnam, Sr Research Associate (until Jun)
J.H. Miranda, Sr Research Associate, Chickpea (until Sep)
L. Krishna Murthy, Sr Research Associate
M. Chenchi Reddy, Sr Research Associate
A. Srinivasan, Postdoctoral Fellow (from Jun)
S.K. Singh, Postdoctoral Fellow (until Jan)
F.B. Lopez, Postdoctoral Fellow (until Jun)
T. Das Gupta, Postdoctoral Fellow (until Oct)
G.S. Chipyngahalo, Research Scholar (until Jun)
A. Schroth, Research Scholar (until Jan)
Uma M. Telugu, Research Scholar (from Jun)
A. Kubota, Research Scholar (from Jun)
L.M.T. Sijen, Research Scholar (until Feb)
G.V. Subba Rao, Research Scholar (until Sep)
M. van Eijk, Research Scholar (from Aug)

Groundnut Group

D. McDonald, Principal Plant Pathologist and Acting Director, Legumes Program (from Apr)
J.P. Moss, Principal Cell Biologist
D.V.R. Reddy, Principal Plant Virologist
J.H. Williams, Principal Plant Physiologist (until May)
J.A. Wightman, Principal Entomologist
S.N. Nigam, Principal Plant Breeder (on sabbatical from Jun)
N. Horn, Assistant Virologist (from Jun)
L.J. Reddy, Plant Breeder
P. Subrahmanyam, Sr Plant Pathologist
P.T.C. Nambiar, Cell Biologist
P.W. Amin, Coordinator and Sr Entomologist, LEGOFTEN
G.V. Ranga Rao, Entomologist
A.K. Singh, Cell Biologist
V.K. Mehan, Plant Pathologist (on sabbatical until May)
D.C. Sastri, Cell Biologist
M.J. Vasudeva Rao, Plant Breeder (until Jan)
S.L. Dwivedi, Plant Breeder
R.C. Nageswara Rao, Crop Physiologist
V.M. Ramraj, Crop Physiologist
N. Sivananda Reddy, Sr Research Associate
Y. Sudhakar, Postdoctoral Fellow (until Apr)
C.C. Gold, Postdoctoral Fellow (until Sep)
W.R. Sacks, Postdoctoral Fellow (until Sep)
Shashi Gupta, Postdoctoral Fellow (until Jan)
J. Watterott, Research Scholar (until Mar)
T. Shanower, Research Scholar (until Apr)
Zhang Xinyan, Research Scholar (until Dec)
Nguyen Hai Nam, Research Scholar
P. Balan, Research Scholar (until Nov)

Kenya

Laxman Singh, Principal Pigeonpea Agronomist (from Sep)

Syria

K.B.Singh, Principal Chickpea Breeder

Pakistan

M.S.Rahman, Principal Chickpea Breeder/
Plant Pathologist (until Aug)

Resource Management

Program Office

J.L. Monteith, Program Director
R.S. Aiyer, Sr Adm Officer
S. Ramachandran, Adm Officer (until Apr)

Agronomy Group

S.M. Virmani, Principal Agroclimatologist
C.K. Ong, Principal Agronomist
D.R. Butler, Principal Microclimatologist
M.M. Anders, Principal Production Agronomist
Piara Singh, Soil Scientist (on sabbatical from Jun to Dec)
A.K.S. Huda, Agroclimatologist
A. Ramakrishna, Agronomist
N. Venkataratnam, Sr Research Associate (from Jun)
S.K. Sharma, Sr Research Associate (from Mar)
L. Mohan Reddy, Sr. Research Associate (from Mar)
A.A.H. Khan, Engineer
J.N. Daniel, Postdoctoral Fellow (until Aug)
J.C.W. Odongo, Postdoctoral Fellow
T. Bapi Reddy, Postdoctoral Fellow (from Dec)
P.P. Motavalli, Postdoctoral Fellow (from Jun)
F.M. Marshall, Research Scholar (from Apr)
S. Ravi Kumar, Research Scholar (from Oct)
R. Ranganathan, Research Scholar (from Oct)

Soil Group

J.R. Burford, Principal Soil Chemist
K.B. Laryea, Principal Soil Physicist
G.D. Smith, Principal Soil Scientist, ICRISAT/QDPI (until Feb)
D.F. Yule, Principal Soil Scientist, ICRISAT/QDPI (from Feb)
K.K. Lee, Principal Microbiologist
A. Schütt, Asst Principal Engineer
(ICRISAT/University of Hamburg)
K.L. Sahrawat, Sr Soil Chemist
T.J. Rego, Soil Scientist
D.P. Verma, Soil Scientist/Soil Chemist,
ICRISAT/IFDC (on contract)
Sardar Singh, Soil Scientist
Prabhakar Pathak, Agricultural Engineer
(on sabbatical until Sep)
K.L. Srivastava, Agricultural Engineer
R.C. Sachan, Agricultural Engineer
N.K. Awadhwal, Agricultural Engineer/Soil Physicist
S.P. Wani, Microbiologist (on sabbatical from Oct)
M. Bonsu, Postdoctoral Fellow (until Aug)
S. Shailaja, Research Scholar (until Apr)
P. Vershney, Research Scholar (until Jun)
S.K. Samantra, Research Scholar (until Nov)
Bibhudutta Das, Research Scholar (from Dec)
M. Dayi S. Abdurahman, Research Scholar (from Sep)
S. Singer, Research Scholar (from May)

Economics Group

T.S. Walker, Principal Economist
R.A.E. Muller, Principal Economist
T.G. Kelley, Asst Principal Economist (from Sep)
N.S. Jodha, Sr Economist II (until Apr)
R.P. Singh, Economist
M. Asokan, Sr Research Associate (on study leave)
K.G. Kshirsagar, Sr Research Associate (on study leave)
K.V. Subba Rao, Sr Research Associate
V. Bhaskar Rao, Sr Research Associate
P. Parthasarathy Rao, Sr Research Associate
A.G. Mengesha, Research Scholar
M. Gautam Research Scholar (until Jul)
M. Bhende, Research Scholar (until Sep)

Support Programs

Biochemistry

R. Jambunathan, Principal Biochemist and Program Leader
Umaid Singh, Biochemist
V. Subramanian, Biochemist
S. Sivaramakrishnan, Biochemist (until Oct)
Santosh Gurtu, Sr Research Associate
M.S. Kherdekar, Sr Research Associate
S. Suryaprakash, Sr Research Associate
P. Venkateshwara Rao, Sr Research Associate
T.R.K. Satyanarayana, Adm Officer (until Jun)
Kamini Devi, Research Scholar (from Apr)

Radio Isotope Lab

S. Sivaramakrishnan, Biochemist (from Oct)

Electron Microscope Unit

A.K. Murthy, Engineer

Genetic Resources

M.H. Mengesha, Principal Germplasm Botanist
and Program Leader
K.E. Prasada Rao, Sr Botanist
R.P.S. Pundir, Botanist II
V. Ramanatha Rao, Botanist II (on leave from Jul)
S. Appa Rao, Botanist II
P. Remanandan, Botanist II (on sabbatical until Jul)
A.K. Singh, Botanist II (from Aug)
Y. Saideshwara Rao, Postdoctoral Fellow (until Jan)
Surendra Mohan, Sr Adm Officer

Plant Quarantine

N.C. Joshi, Chief Plant Quarantine Officer (on contract)
Upendra Ravi, Sr Research Associate
V.S. Raju, Adm Officer (until Apr)
P. Subrahmanyam, Sr Adm Officer (from Apr)

Fellowships and Training

D.L. Oswalt, Principal Training Officer and Program Leader
B. Diwakar, Sr Training Officer
T. Nagur, Sr Training Officer
S.K. Dasgupta, Sr Training Officer
Faujdar Singh, Training Officer

Information Services

J.B. Wills, Head
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E.M. McGaw, Research Editor (from Jun)
S.M. Sinha, Asst Manager, Art and Production
D.R. Mohan Raj, Sr Editor (on leave from Jun)
J.J. Abraham, Editor
V. Sadhana, Editor
G.K. Guglani, Sr Art Visualizer
T.R. Kapoor, Sr Composing Supervisor
A. Antonisamy, Printshop Supervisor
A.B. Chitnis, Sr Photographer
A.N. Venkataswami, Sr Adm Officer
B.B. Sahni, Editor (on contract from Sep)
Savitri Mohapatra, Sr French Translator

Statistics

Murari Singh, Statistician (until Jun)

Computer Services

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J. Sai Prasad, Asst Manager (Computer Services)
T.B.R.N. Gupta, Senior Computer Programmer/Analyst
S.V. Nanda Kishore, Computer Programmer/Analyst (until Apr)
G. Subba Raju, Computer Programmer/Analyst
G. Padmaja, Computer Programmer/Analyst
A. Ram Murthy, Computer Programmer/Analyst (from Dec)

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S. Prasannalakshmi, Sr Library Officer
R.G. Naidu, Documentation Officer
V. Venkatesan, Library Officer (on leave until May)
Daulat Jotwani, Library Officer

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S. Mazumdar, Asst Manager (Food Services)
B.R. Revathi Rao, Asst Manager (Housing)
D.V. Subba Rao, Asst Manager (Warehouse)
D.N. Sar, Canteen Officer
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V.S. Raju, Adm Officer (from Apr)

Physical Plant Services

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D. Subramaniam, Manager (Acting)
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N.S.S. Prasad, Sr Engineer (Electronics and Instrumentation)
A.R. Das Gupta, Sr Engineer (Communication) (on secondment to Niger)
D.C. Raizada, Sr Engineer (Airconditioning)
A.N. Singh, Engineer (Heavy Equipment and Tractors) (on leave until Jun)
S.W. Quader, Engineer (Office Equipment) (until Sep)
K.R.C. Bose, Engineer (Civil) (on secondment to Mali)
K. Satyanarayana Raju, Engineer (Machine shop)
V. Madhusudan Rao, Engineer (Electronics and Instrumentation)
Y. Chiranjeevi Rao, Engineer (Electrical)
R. Parameswaran, Engineer (Auto) (from Aug)
S.P. Jaya Kumar, Sr Adm Officer

Farm Development and Operations

D.S. Bisht, Manager
S.K. Pal, Sr Plant Protection Officer II
K. Ravindranath, Sr Engineer (Farm Machinery)
M. Prabhakar Reddy, Sr Agricultural Officer
N.V. Subba Reddy, Sr Horticulture Officer
M.C. Ranganatha Rao, Sr Engineer
S. Abid Ali Khan, Agricultural Officer
C. Rama Reddy, Agricultural Officer
Akbar Pasha, Engineer
S.C. Gupta, Engineer
A. Hameed, Adm Officer (until Apr)
S. Ramachandran, Adm Officer (from Apr)

West African Programs

ICRISAT Sahelian Center, Niger

Administration

R.W. Gibbons, Executive Director, West African Programs, and Director, ICRISAT Sahelian Center
A. Jagne, Regional Adm Officer
K.P. Nair, Regional Purchase and Supplies Manager
M.D. Diallo, Regional Fiscal Officer
J. Banji, Purchase Officer (On special assignment, until Apr)
S. Delanne, Executive Asst (Liaison)
I.J. Cachalo, Bilingual Secretary
K.A. Moussa, Personnel and Transport Officer

Research Programs

Pearl Millet Improvement Program

K. Anand Kumar, Principal Millet Breeder and Team Leader
L.K. Fussell, Principal Millet Agronomist
S.O. Okiror, Principal Millet Breeder/Regional Trials Officer

J. Werder, Principal Millet Pathologist
M.J. Lukefahr, Principal Millet Entomologist
L. Marchais, Principal Geneticist (ORSTOM)
S. Tostain, Principal Geneticist (ORSTOM)

Groundnut Improvement Program

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

Resource Management Program

C. Renard, Principal Agronomist and Team Leader
M.C. Klaij, Principal Soil and Water Management Scientist
M.V.K. Sivakumar, Principal Agroclimatologist
J. Baidu-Forson, Principal Economist
R.J. Van Den Beldt, Principal Agronomist/Agroforestry
J.H. Williams, Principal Physiologist (from Jun)
A. Bationo, Principal Soil Chemist (IFDC)
B.R. N'tare, Principal Cowpea Breeder/Agronomist (IITA)
J.C. Hopkins, Visiting Scientist (IFPRI)
J. Lambourne, Principal Animal Nutritionist, Special Consultant (ILCA)
M. Welte, Program Corodinator, University of Hohenheim
J. Toll, IBPGR Field Officer for West Africa
M. Powell, Principal Agroecologist (from Aug) (ILCA)
D.B. Roxas, Principal Animal Nutritionist (from Sep) (ILCA)
T.O. Williams, Principal Economist (from Oct) (ILCA)
P. Ouedraogo, Sr Research Asst

Support Programs

Farm Operations

P.G. Serafini, Research Farm Manager (on sabbatical until Aug)
P. Koudogbo, Chief Mechanic (until Jul)
R. van Midde, Farm Manager (until Jul)

Physical Plant Services

A.R. Das Gupta, Manager
J. Henry, Training Consultant (Mechanic)

Construction

V.P. McGough, Facilities Unit Manager

Statistics

B. Gilliver, Principal Statistician (until Aug)
G. Ouoba, Computer Programmer

Information/Documentation

C. Giroux, Regional Information Officer (on sabbatical)

Training

J.Q. Nguyen, Principal Training Officer (from Aug)

West African Sorghum Improvement Program (WASIP)

Mali

Administration

K.V. Ramaiah, Principal Cereal Breeder—*Striga* and Team Leader
A. Schulz, Administrator
K.R.C. Bose, Project Development Officer

Research

M.D. Thomas, Principal Sorghum Pathologist and SAFGRAD/ICRISAT Coordinator (from May)
S.N. Lohani, Principal Millet Breeder (on sabbatical until Mar)
A. Adesina, Asst Principal Economist
G. Hoffman, Principal *Striga* Agronomist (CIRAD)
P. Salez, Principal Agronomist (IRAT)
A. Ratnadas, Principal Entomologist (IRAT)
C. Luce, Principal Breeder (IRAT)

Nigeria

Administration

O. Ajayi, Principal Sorghum Entomologist and Team Leader
A. Banerji, Adm Officer

Research

D.S. Murty, Principal Sorghum Breeder
R. Tabo, Principal Sorghum Agronomist
S.N. Kapoor, Farm Manager (until Apr)
D.J. Flower, Principal Physiologist
R. Stumpo, Asst Principal Physiologist

Mali Bilateral Program

S.V.R. Shetty, Principal Agronomist and Team Leader
N.F. Beninati, Principal Breeder

Southern Africa Programs

SADCC Regional Sorghum and Millet Improvement Program (Zimbabwe)

L.R. House, Executive Director, Southern Africa and Project Manager, SADCC/ICRISAT Program

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S.C. Gupta, Principal Forage and Millet Breeder
W.A.J. de Milliano, Principal Cereals Pathologist
M. Osmanzai, Principal Cereals Agronomist
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D. Rohrbach, Principal Economist
H. Ssali, Soil Scientist (IFDC)
M.I. Gomez, Principal Food Technologist
C.M. Matanyaire, Principal Station Management and Development Officer
L. Tendengu, Regional Training Officer
N. Katuli, Regional Station Development and Operations Officer
E. Monyo, Postdoctoral Fellow
W.K. Morgan, Asst Adm Officer (until May)
Z.M. Mhlanga, Asst Adm Officer (from Sep)
R. Nxumalo, Sr Accountant (until Jun)
N. Mwamuka, Research Technician - Grade II
P. Chingombe, Research Technician - Grade II
F. Munaku, Research Technician - Grade II

SADCC/ICRISAT Groundnut Project (Malawi)

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G.L. Hildebrand, Principal Groundnut Breeder
V.S. Swaminathan, Adm Officer (from May)

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