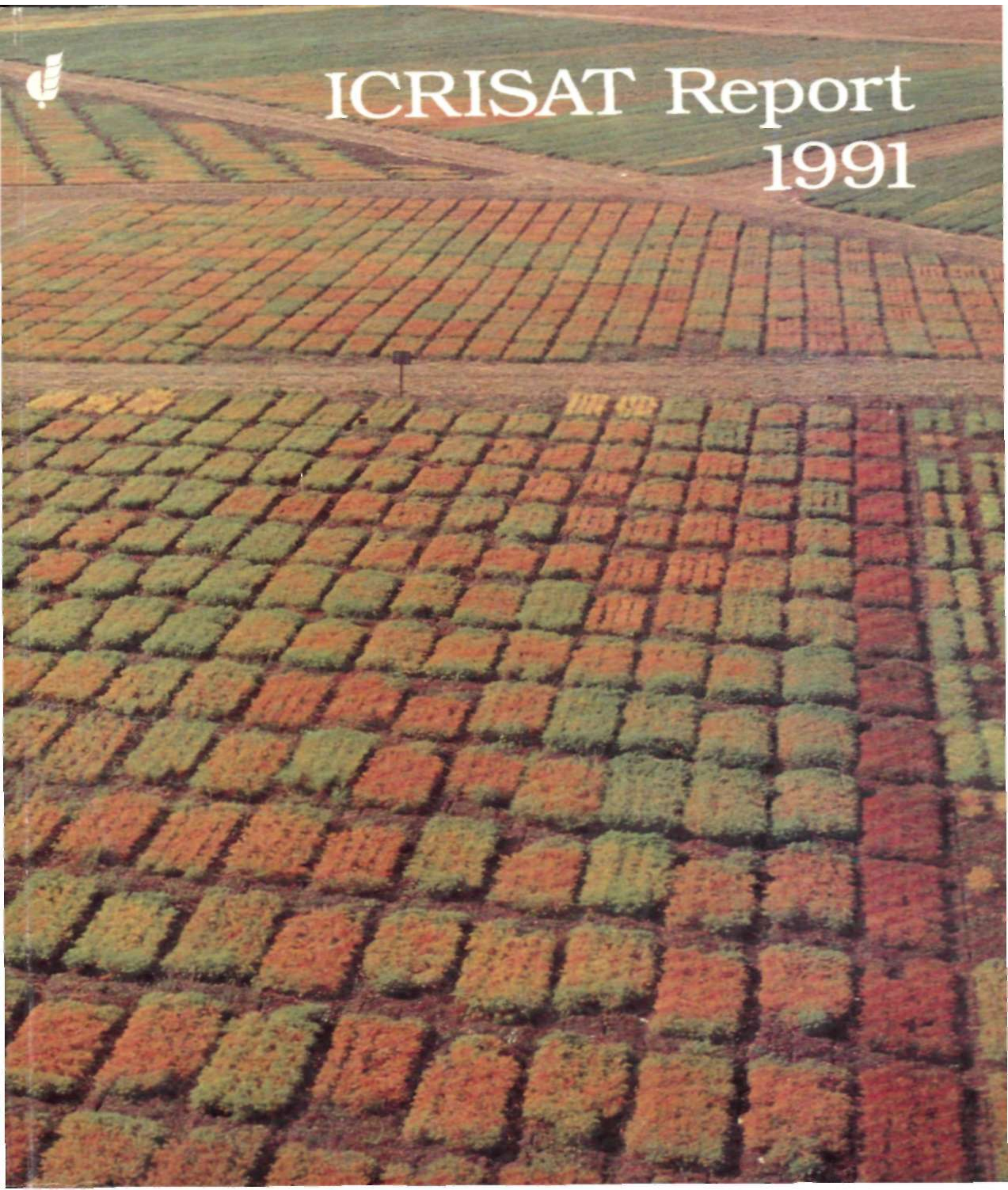
# ICRISAT Report 1991



# Abstract

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*ICRISAT Report 1991 is the Institute's progress report intended to reach diverse range of readers. The publication includes the Director General's account of 1991 research highlights, and four designated themes that illustrate the Institute's progress in the recent pasf: Agroclimatic Zoning; Agroforestry and Perennial Systems; Crop Utilization; and Genetic Resources and Gennplasm Enliancement. Appendices include Financial Highlights, a list of published work by the Institute's staff during the year, and a list of senior staff. A supplement covering the achievements of the 20 years of the Institute's history is incorporated.*

## Résumé

**Rapport d'activité de l'ICRISAT 1991.** *Ce document est conçu pour diverses catégories de lecteurs. Il présente le rapport du Directeur général sur les résultats marquants obtenus en 1991 ainsi que quatre thèmes illustrant les progrès réalisés récemment par l'Institut: zonage agroclimatique; agroforesterie et systèmes pérennes; utilisation des cultures; augmentation et exploitation des ressources phytogénétiques. L'état financier, une liste des publications et une liste des cadres de l'Institut sont donnés en annexe. Un supplément décrivant les réalisations de l'Institut au cours des 20 ans est incorporé.*

## Resumen

**Informe del ICRISAT 1991.** El ICRISAT *Report 1991 es el informe de progreso del Instituto que pretende llegar a diversos tipos de lectores. La publicación incluye la relación del Director General de los aspectos más importantes de la investigación en 1991, y cuatro temas seleccionados que ilustran el avance del Instituto en los últimos años: zonificación agroclimática, agrosivicultura y sistemas perennes, utilización de cosechas e intensificación de los recursos genéticos y del plasma germinal. Los Apéndices incluyen los aspectos financieros más importantes, una lista de trabajos publicados durante el año por el personal del Instituto y una lista del personal directivo. Se incorpora un suplemento que expone los logros obtenidos en los 20 años de historia del Instituto.*

***Cover**. Over 4000 entries in a chickpea nursery being tested for drought resistance at ICRISAT Center in January 1991. The yellow and brown plants are short- and extra-short-duration genotypes approaching maturity.*

# ICRISAT Report 1991

ICRISAT

International Crops Research Institute for the Semi-Arid Tropics
Patancheru, Andhra Pradesh 502 324, India

1992

The International Crops Research Institute for the Semi-Arid Tropics is a nonprofit, scientific, research and training institute receiving support from donors through the Consultative Group on International Agricultural Research. Donors to ICRISAT include governments and agencies of Australia, Belgium, Canada, China, Finland, France, Germany, India, Italy, Japan, Netherlands, Norway, Sweden, Switzerland, United Kingdom, United States of America, and the following international and private organizations: African Development Bank, Asian Development Bank, Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ), International Board for Plant Genetic Resources, International Development Research Centre, International Fertilizer Development Center, International Fund for Agricullural Development, The European Economic Community, The Opec Fund for International Development, The Rockefeller Foundation, The World Bank, United Nations Development Programme, University of GeoTgia, and University of Hohenheim. Information and conclusions in this publication do not necessarily reflect the position of the aforementioned governments, agencies, and international and private organizations.



This Report is intended to reach diverse range of readers. For detailed results of research conducted in 1991, consult Program-level Annual Reports available from Cereals, Legumes and Resource Management Programs, and Genetic Resources Unit, at ICR1SAT Center, and from ICRISAT Sahelian Center (Niger) and SADCC/1CRISAT (Zimbabwe).

# Contents

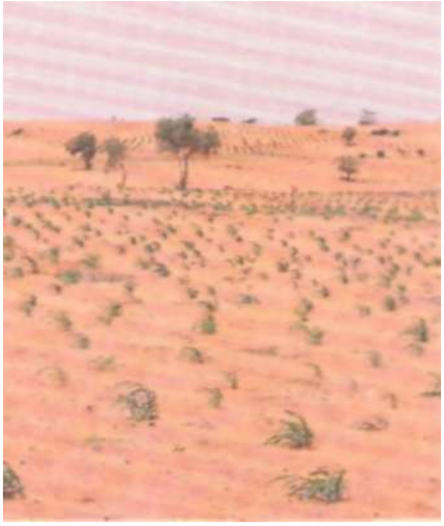
# ICRISAT's Mandate

1. *Serve as a world center for the improvement of grain yield and quality of sorghum, millets, chickpea, pigeonpea, and groundnut and act as a world repository for the genetic resources of these crops.*

2. *Develop improved farnting 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.*

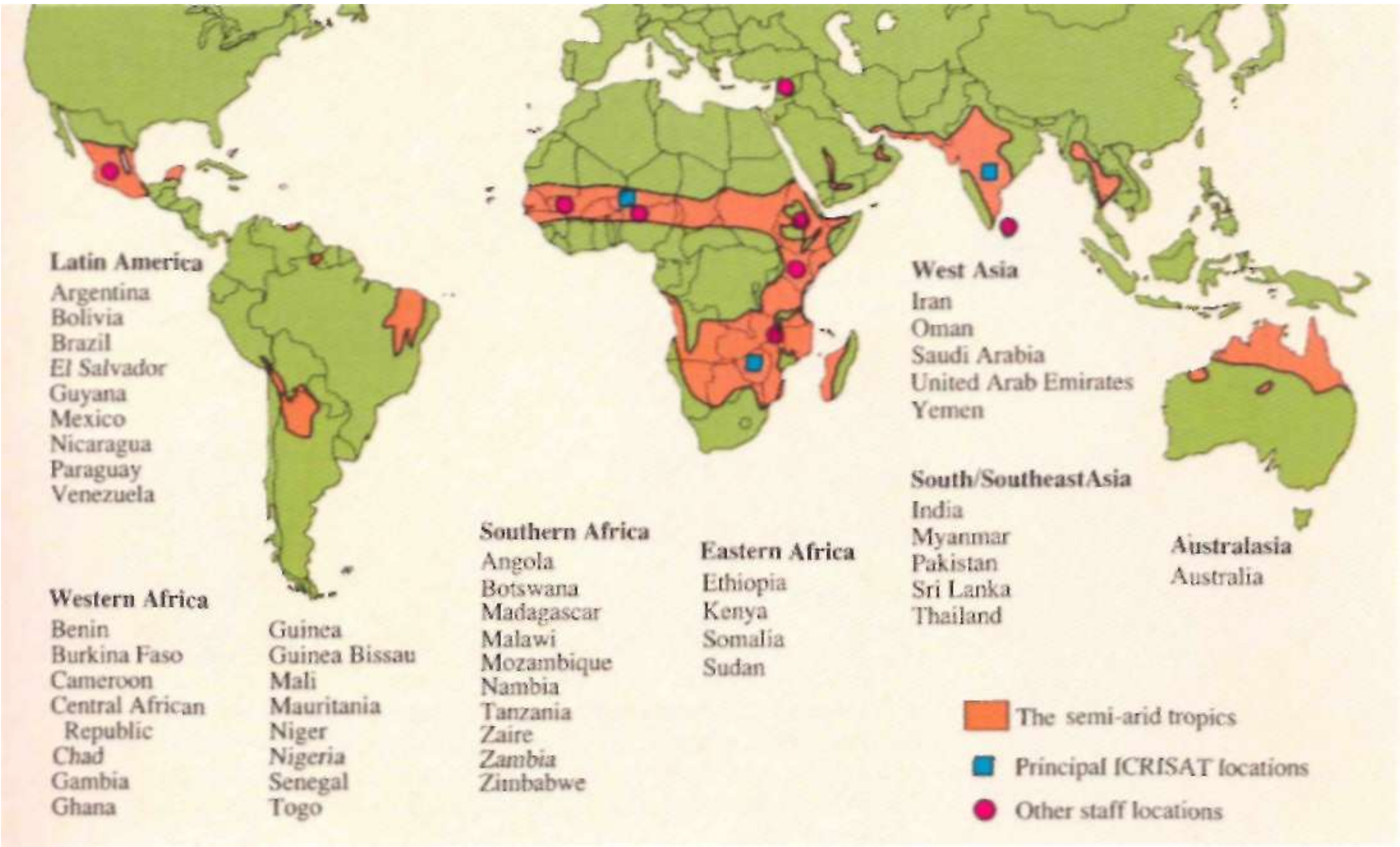
3. *Identify constraints to agricultural development in the semi-arid tropics and evaluate means of alleviating them through technological and institutional changes.*

-i. *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 miller growing in the harsh environment of Sahelian Africa.*

## ICRISAT's Partners in the Semi-Arid Tropics



# The Mandate Crops

## Sorghum

*Sorghum bicolor* (L.) Moench

| | | |
|---|---|---|
| French | : | sorgho |
| Portuguese | : | sorgo |
| Spanish | : | sorgo |
| Hindi | | jowar, jaur |

Sorghum is the fifth most important cereal in the world and a major staple in the diets of the people of the semi-arid tropics (SAT). It is the second most important cereal in Africa and is next in importance to rice and wheat in India. Sorghum is grown on over 40 million hectares. It is a hardy and dependable crop that grows well under adverse conditions. Sorghum has many uses. As a human food it is ground into flour and made into porridges and bread. The grain is also used as feed for animals, particularly in the Americas. Sorghum stalks provide fodder, fuel, shelter, sugar, and syrup.

## Pearl Millet

*Pennisetum glaucum* (L.) R.Br.

| | | |
|---|---|---|
| French | : | mil |
| Portuguese | : | panico perola |
| Spanish | : | mijo perla |
| Hindi | : | bajra |

Pearl millet is the world's sixth most important cereal. The most widely cultivated millet in the SAT, it is grown on an estimated 25 million hectares. It is suited to dry regions with sandy infertile soils where rainfall is low and erratic. It can be successfully cultivated in areas too dry for sorghum. The grain is used to make unleavened bread *(chapatis)* on the Indian subcontinent and prepared as gruel, dumplings, *couscous,* and beer in Africa. It is also used as animal feed and forage.

## Finger Millet

*Eleusme comcana* (L.) Gaertn.

| | | |
|---|---|---|
| French | : | eleusine |
| Portuguese | : | maxoeira |
| Spanish | : | mijo digitado, mijo coracano |
| Hindi | : | ragi |

Finger millet, an important cereal in Africa and India in areas with 900-1200 mm of rainfall per annum, was designated in 1990 as an additional millet for special study in the highlands of eastern and southern Africa, where it is particularly important as a food crop. It is rich in minerals such as calcium and iron.

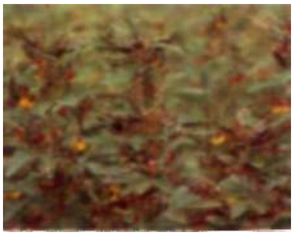
## Chickpea

*Cicer arietiman* L.

French : pois chiche
Portuguese : grao-de-bico
Spanish : garbanzo
Hindi chana

Chickpea is the most important pulse crop in South Asia where the small-seeded desi type predominates. In West Asia and northern Africa, the larger-seeded kabuli types are more important. Chickpea cultivation is increasing in Australia, Mexico, the southern USA, and eastern Africa. Chickpea is an important source of protein and is of particular significance in the largely vegetarian diets of South Asia. The grain and haulms are used as animal feed.

## Pigeonpea



*Cajanus cajan* (L.) Millsp.

French : pois d'Angole
Portuguese guando
Spanish : guandul
Hindi : arhar, tur

Pigeonpea, like chickpea, is predominantly a crop of South Asia. However, its importance as a pulse crop in the Caribbean region and in eastern Africa is increasing. The true extent of this crop is difficult to estimate as pigeonpeas are often grown as intercrops or as hedges and windbreaks. The crop provides forage, green manure, and fuelwood. Prepared and consumed in a wide variety of forms, pigeonpea is important to many people in the SAT.

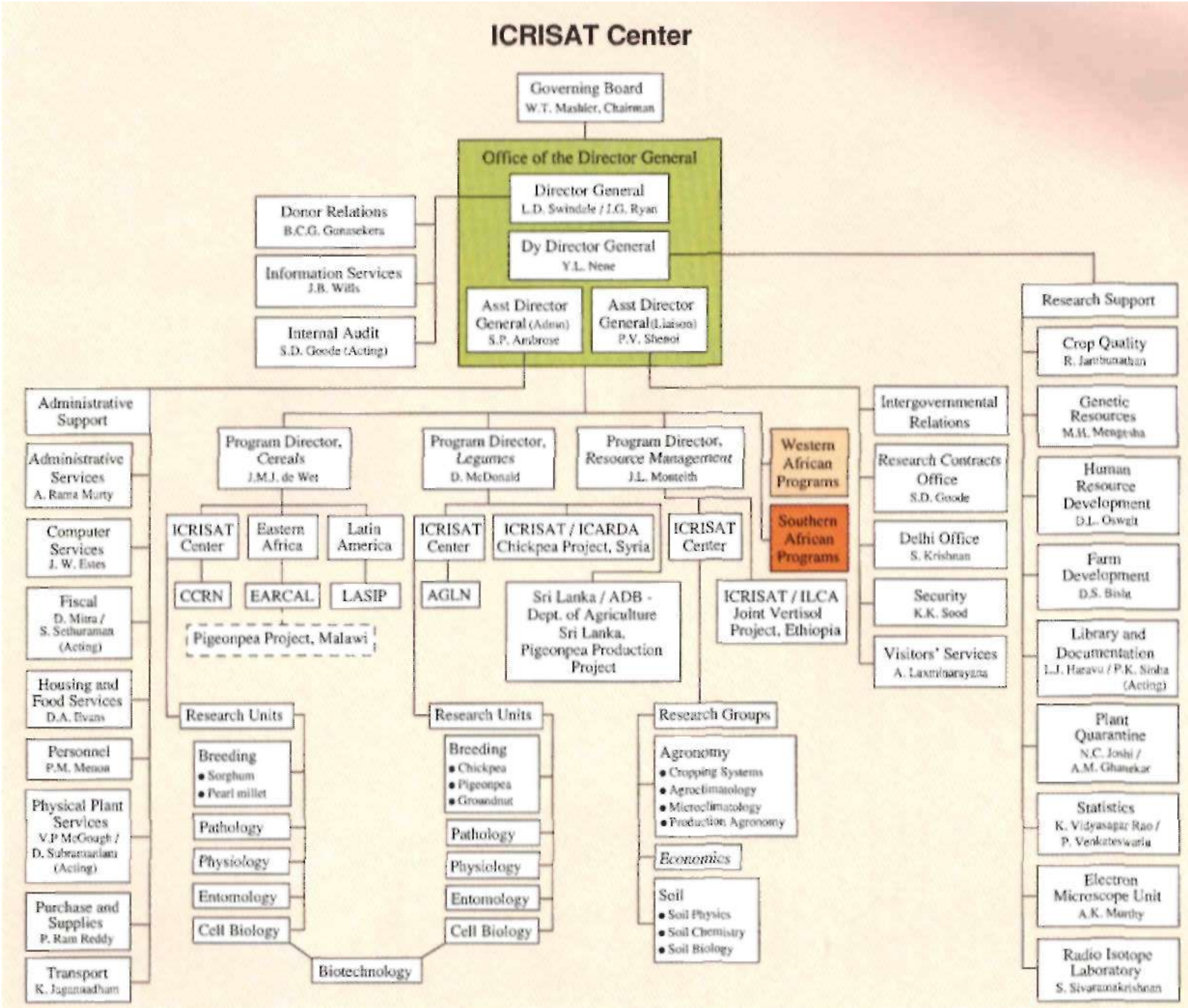
## Groundnut

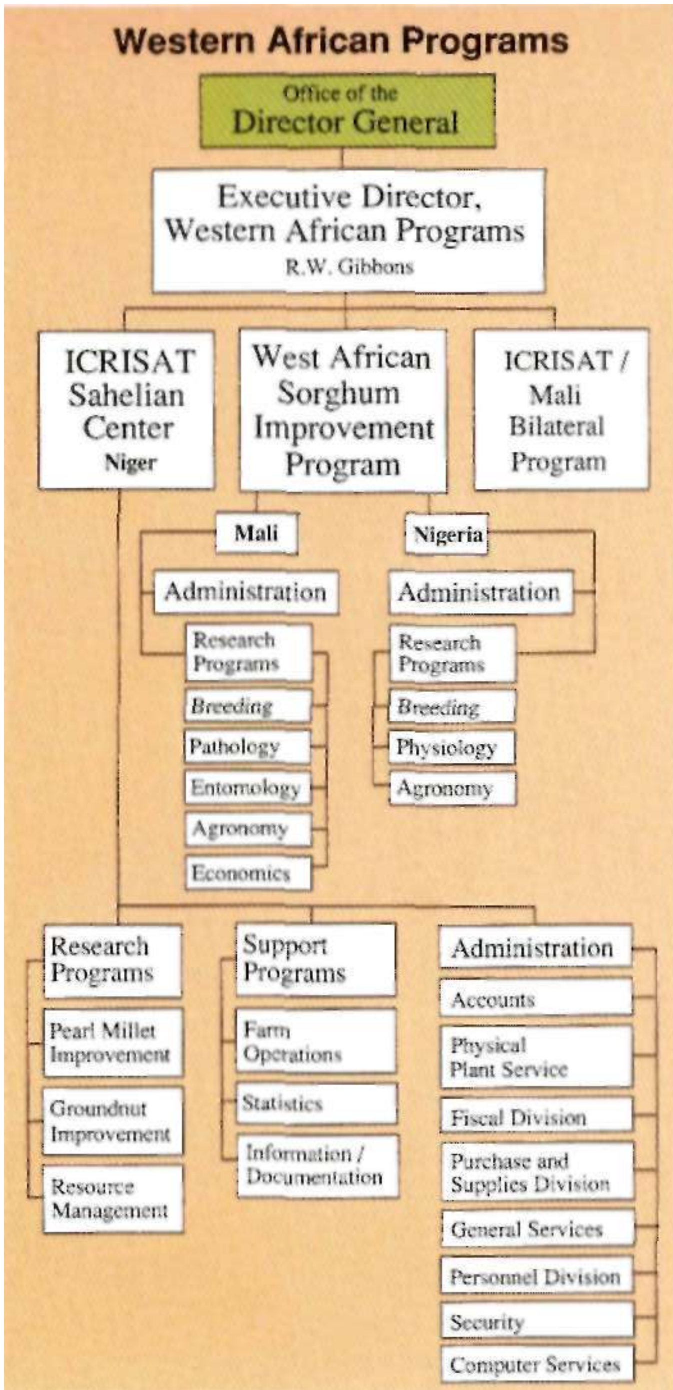
*Arachis hypogaea* L.

French : arachide
Portuguese : amendoim
Spanish : mam, cacahuate
Hindi : mungphali

Groundnut is widely grown between latitudes 40°N and 40°S and is the most important oilseed of the SAT. It provides a high-quality cooking oil and is an important source of protein for both humans and animals. The haulms are important as livestock feed, especially in the drier parts of the SAT. Groundnut is a cash crop for many resource-poor farmers; it also provides much needed foreign exchange to semi-arid tropical countries when sold in the international market.

# Organization Charts





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Breeding
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Entomology
Agronomy
Economics
Administration
Research
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Breeding
Physiology
Agronomy
Research
Programs
Pearl Millet
Improvement
Groundnut
Improvement
Resource
Management
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Programs
Farm
Operations
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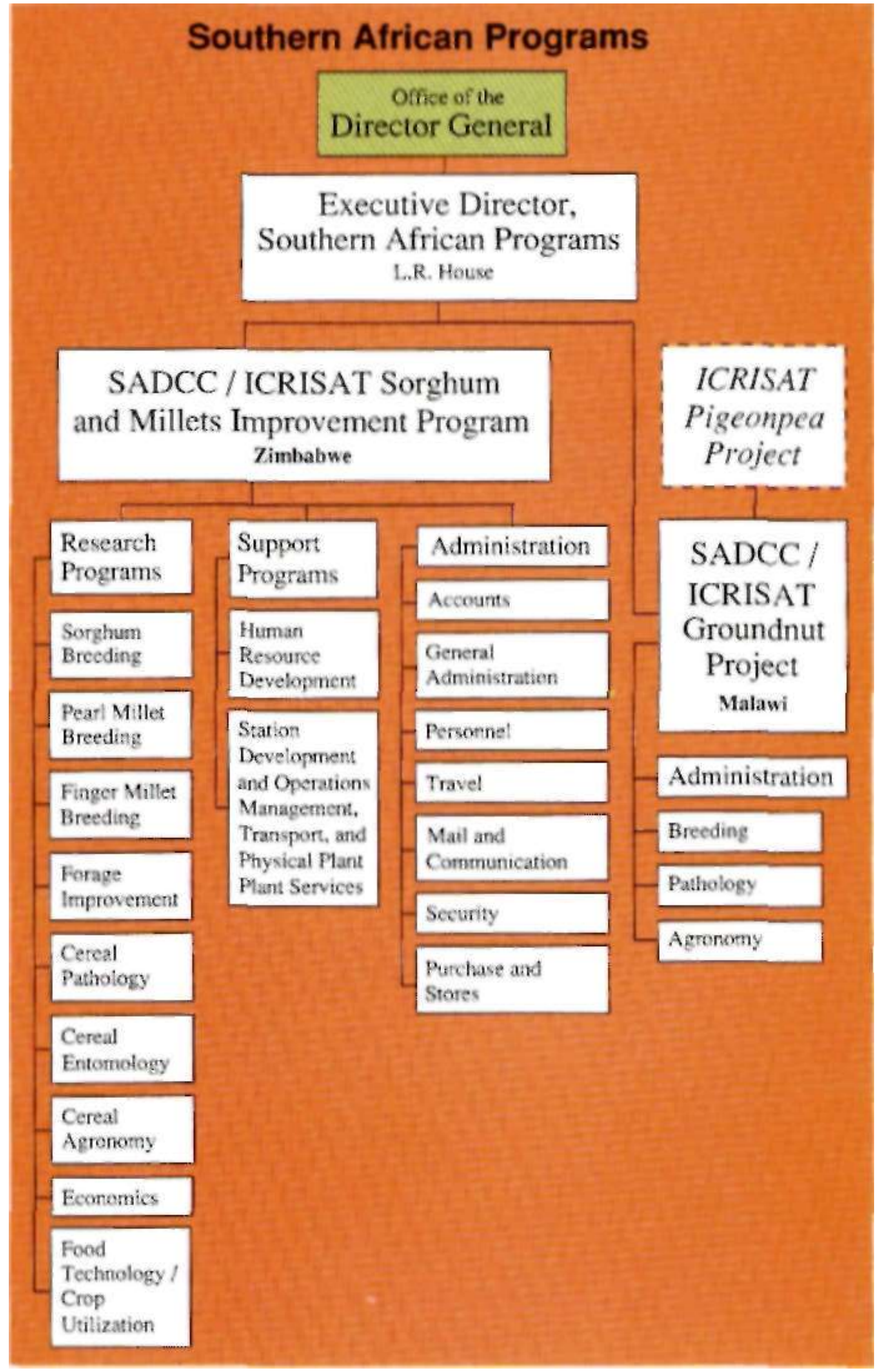
Plant Service
Fiscal Division
Purchase and
Supplies Division
General Services
Personnel Division
Security
Computer Services

Southern African Programs
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L.R. House
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Pearl Millet
Breeding
Finger Millet
Breeding
Forage
Improvement
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Pathology
Cereal
Entomology
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Human
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Malawi
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Breeding
Pathology
Agronomy

# Where We Work

The Institute's headquarters—ICRISAT Center—is located at Patancheru, in Andhra Pradesh state, India. ICRISAT Sahelian Center, at Sadore, near Niamey, Niger, is the Institute's largest facility outside of India. ICRISAT scientists are also posted in six other African countries (Ethiopia, Kenya, Malawi, Mali, Nigeria, and Zimbabwe), and *in* Mexico and Syria. ICRISAT closely monitors the ICRISAT/Asian Development Bank (ADB)-Department of Agriculture, Sri Lanka Pigeonpea Production Project, although at present no staff member is permanently posted there.


## ICRISAT Center

ICRISAT Center lies 26 km northwest of Hyderabad, capital of Andhra Pradesh state. The farm extends over 1391 hectares and includes two major soil types found in the semi-arid tropics (SAT): Alfisols (red soils) and Vertisols (black soils). Alfisols are light and prone to drought Vertisols retain two to three times as much water as Alfisols in the soil profile near the roots of crops. Access to both soil types enables ICRISAT scientists to conduct experiments under conditions representative of many semi-arid tropical areas.

The Center has three major programs." Cereals and Legumes crop improvement programs, and a Resource Management Program. The crop improvement teams consist of breeders, geneticists, cell biologists, physiologists, agronomists, pathologists, virologists, nematologists, entomologists, germplasm botanists, and biochemists.

The Resource Management Program integrates the work of its scientists concerned with crop production in relation to weather, soil conditions, pests, and weeds; of its scientists and engineers working on the conservation of water and soil; and of its economists who evaluate new technology in terms of the human and institutional constraints that limit its adoption, associated costs and benefits, and consequences for nutrition and social structure.

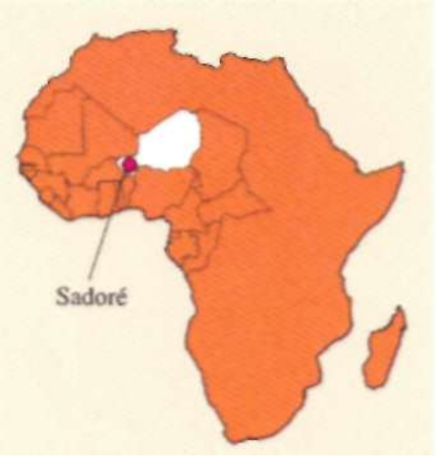
**Seasons.** Three distinct seasons characterize the Indian SAT. In the Hyderabad area, the rainy season, also known as the monsoon or kharif, usually begins in June and extends into early October. Because more than 80% of the annual rainfall (usually about 780 mm) occurs during this period, rainfed *crops* are constrained by a limited growing season- The postrainy season (mid-October through January), also known as *rabi,* is dry and cool. During this period, crops can be grown on Vertisols using stored soil moisture and on Alfisols with irrigation. The hot, dry season, which begins in February, lasts until rains begin again in June. Any crop grown during this season requires irrigation.

**Crops.** ICRISAT's mandate crops have different environmental requirements that determine when and where they are grown. Pearl millet and groundnut are usually sown on Alfisols during June and July at the beginning of the rainy season. They are also grown as postrainy-season crops. Pigeonpea is generally sown at the beginning of the rainy season and continues to grow through the postrainy season. An irrigated crop of short-duration pigeonpea is also sown in

December to provide genetic material for the breeding programs. Two sorghum crops are grown at the Center each year, one on both Alf'isols and Vertisols during the rainy season and the other only on Vertisols in the postrainy season. Chickpea, a single-season crop, is grown on Vertisols during the postrainy season on residual soil moisture.

**Weather.** In 1991, the total annual rainfall at Patancheru was 843 mm which was similar to the 1990 total of 831 mm. Rain early in the year benefited the 1990 postrainy-season crops. There was sufficient rain early in the monsoon to allow early sowing and crop establishment in both Vertisol and Alfisol areas. This early onset of rain was followed by nearly 100 days of well-distributed rainfall. Initial crop growth was excellent with nearly all rainy-season crops yielding well. The remainder of the rainy season consisted of two rainy periods with the second occurring after the sowing of postrainy-season crops. No rain fell after 22 October. However, earlier rains were sufficient for postrainy-season crops to produce high yields.

## ICRISAT Sahelian Center (ISC), Niger

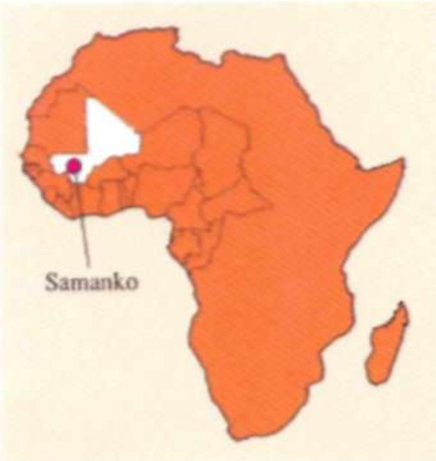



ISC is ICRISAT's principal research base in the Sahelian region of western Africa. The Center has three programs: the Pearl Millet and Groundnut Improvement Programs and a Resource Management Program, which investigates the farming systems associated with these crops. The Center is located at Sadore, near the village of Say, 45 km south of the capital city of Niamey. The experimental farm extends over 500 hectares of crumbly, reddish, sandy soils with low native fertility' and low organic matter content.

**Seasons.** The climate in Sadore is characterized by a short rainy season (about 90 days) from June to September. The average annual rainfall is 570 mm. It is irregular and normally comes in the form of electrical storms. During the dry season, dust storms from the north and east frequently occur. Temperatures are warm all the year round and average 29°C.

**Crops.** The rnain crop in the Niamey region is short-duration pearl millet. It is sown with the first rains. An irrigated nursery is cultivated at ISC from January to April to advance generations and help in seed multiplication. Intercropping pearl millet with cowpea, the region's major legume, is common. Cowpea is normally sown between pearl millet rows 2-3 weeks after the pearl millet emerges, by which time rains are more frequent.

**Weather.** Rainfall at ISC during 1991 was 603 mm, 6% above average. Rainfall from May through August totalled 547 mm and was well distributed, which resulted in good vegetative growth and grain filling of pearl millet, but favored heavy infestation by insect pests. The September rain, of only 13 mm during the first 12 days of the month followed by a dry spell of 18 days, is the lowest ever recorded over the last 85 years. This affected the growth of intercropped cowpea and long-duration pearl millet.




## Mali

The West African Sorghum Improvement Program (WASIP)-Mali complex at Samanko, near Bamako, the capital of Mali, occupies 100 hectares along the Niger river. An interdisciplinary team of scientists from ICRISAT and Centre de cooperation internationale en recherche agronomique pour le developpement (CIRAD) evaluates sustainable land-use systems for farming areas constrained by a 150-day growing season. Emphasis is placed on breeding medium- and long-duration sorghum varieties with appropriate levels of resistance to biotic stresses. The soil consists mainly of loam and clay Sorghum, pearl millet, groundnut, and maize are the major crops. Total rainfall in 1991 was 1048 mm, 3% below average compared to the low rainfall of 1990 that was 23% below average. However, rains during the 1991 cropping season were good at Samanko and well distributed over 78 effective rainy days. The maximum rain was received in July (310 mm). The October rains provided ideal conditions that led to grain mold on the sorghum crop- The ICRISAT-Mali Bilateral Program, operating through Institut d'economie rurale (IER), which terminated in May operated from the Sotuba Research Station, also located near Bamako. The Sotuba Station typifies the Sudanian Zone of sub-Saharan Africa.


## Nigeria

Bagauda Research Station near Kano in northern Nigeria, is the other regional base for ICRISAT's WASIP. The main thrust at Bagauda is to screen high-yielding sorghum cultivars of good quality and to determine the agronomic requirements for sustainable production in the Sahel. Total rainfall for 1991 was 934 mm, 12% above the long-term average of 834 mm for Kano. Crop establishment and performance were satisfactory in spite of soil erosion on the farm because of heavy rains in July and August, and an inadequate drainage system. Rainfall during the growing season (Jun-Oct) was 709 mm, 5.84% above the long-term average. Spittle bug and stem borer infestations were severe this year. Improved but drought-susceptible cultivars also suffered from terminal drought, which resulted in stem lodging.


## SADCC/ICRISAT SMIP, Zimbabwe

Southern African Development Coordination Conference (SADCC)/ ICRISAT Sorghum and Millets Improvement Program (SMIP) for the 10 countries of the SADCC region is based at Matopos, near Bulawayo, in southwestern Zimbabwe. The SADCC countries are Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, Swaziland, Tanzania, Zambia, and Zimbabwe. Facilities here are second only to ISC among locations outside ICRISAT Center. The growing season lasts from October/November to March/April Soils range from sand to clay Rainfall between September 1990 and August 1991 was 521 mm (11% less than average), which resulted in a below-average crop yield. Sorghum at the early stages of growth preceding flowering faced a prolonged dry spell around mid-December, which continued until mid-January. A heavy hailstorm on 22 February damaged and defoliated the crop by 80% at Sandveld West Acre, 5-10% at Matopos, and 10-15% at Sandveld Lucydale.

## Malawi

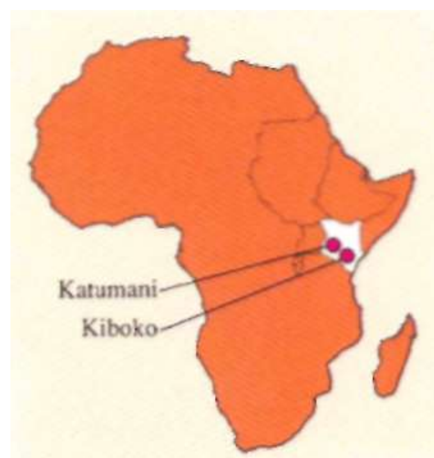

The Chitedze Agricultural Research Station of the Ministry of Agriculture and Livestock Development, Malawi, is located on the Lilongwe Plain, east of the capital. It provides a base for the SADCC/ICRISAT Groundnut Project and ICRISAT's project on the improvement of pigeonpea in southern Africa. The area has a tropical continental climate with one rainy season from October/November to March/April, typical of groundnut-growing areas in southern Africa. Rainfall during the groundnut-growing season was 634 mm (34% below the normal 957 mm) with well-distributed rain during the cropping season from November to April. Soil moisture in the postrainy season was not enough to ensure a good germination and emergence of groundnut but the clear hot weather favored early crop growth.

# Other Locations

## Ethiopia

An ICRISAT scientist is based in Ethiopia at the International Livestock Centre for Africa (ILCA) to work on a Joint Vertisol Project in cooperation with the scientists of Ethiopia's Institute for Agricultural Research, Alemaya University of Agriculture (AUA), and ILCA. The objective of this collaborative work is to develop Vertisol watersheds at sites neax Addis Ababa. During 1991, ICRISAT collaborated on experiments at Ginchi, Akiki, and Debre Zeit. Ginchi received 909 nun of rain, which is about 20% below the annual average of 1141 mm. The growth of postrainy-season crops was affected as October was almost dry.

## Kenya




ICRISAT's Eastern Africa Regional Cereals and Legumes (EARCAL) program is based in Nairobi. EARCAL has seven member countries: Burundi, Ethiopia, Kenya, Rwanda, Somalia, Sudan, and Uganda. Its work is to evaluate sorghum and millet genotypes in four major agroecological zones: highlands, intermediate elevations, low elevations, and very dry lowlands. Researchers screen sorghum, pearl millet, and pigeonpea for dry short-season adaptation in the long rains, and intermediate adaptation in the short rains. The Kenya Agricultural Research Institute (KARI) has provided land to ICRISAT at its Katumani and Kiboko stations, and research facilities at stations in other agroecological zones. As 1991 was dry, the pigeonpea crop suffered from the drought at lower elevations in eastern Kenya.

**Katumani.** This site is located 1°S of the Equator, 10 km from the town of Machakos. The altitude is 1575 m and the rainfall, which averages 718 mm, is bimodal. The first rainfall period peaks in April and the second in November. The soils here are a loamy reddish-brown. They are deep and well drained. In 1991, total rainfall was 652 mm, 9% below normal.

**Kiboko.** Kiboko is located 170 km southeast of Nairobi on an erosional plain at an altitude of 1300 m. The soil is a friable clay loam, and reddish-brown or dark red. During 1991, rainfall was 566 mm, 6% below normal of 600 mm. The first short-duration pigeonpea crop season *(Nov-Feb)* received 276 mm and second crop season (Mar-May) received only 143 mm of rainfall. The long-duration pigeonpea cultivars grown were a total failure, and medium- and short-duration cultivars produced suboptimal yields.

## Mexico

ICRISAT's team in Mexico is based at the Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT), at El Batan, north of Mexico City. Here research is carried out on high-altitude, cold-tolerant sorghums adapted for low and intermediate elevations in South and Central America. The rainfall at El Batan totalled 696 mm in 1991,111% above average. The rains began in April, a month early, and lasted 1 month beyond the normal season. The *rainfall throughout* the rainy months was far above normal and very well distributed. As a result, there was no killing frost during the crop cycle and all highland material reached physiological maturity. The temperatures were also above normal, and all crops performed well.

## Sri Lanka

The ICRISAT/ADB-Department of Agriculture, Sri Lanka Pigeonpea Production Project is based at Maha Illuppallama. The total annual rainfall was 1192 mm, 19% below the average of 1475 mm. However, there was an abundance of moisture. Crop growth in general was excellent in all the on-farm demonstrations covering about 50 hectares in three districts. During this year the rains were extended and well distributed. However, as rainy days from mid-December to mid-January *were more than usual the* pest-control program was adversely affected. The rains hindered effective pesticide application.

## Syria

In Syria, ICRISAT cooperates with the International Center for Agricultural Research in the Dry Areas (ICARDA) near Aleppo, in northwestern Syria. The two centers share the world mandate for chickpea, although ICARDA's focus is on the kabuli types that are sown in spring or winter in the West Asia and northern Africa (WANA) region and in certain areas of Latin America. ICRISAT's work on kabuli cultivars is therefore conducted primarily at Tel Hadya, near Aleppo. (Most work on desi and some on kabuli chickpeas is carried out at ICRISAT Center.) The growing season in Aleppo lasts from November to June. Total rainfall received in the 1990/91 cropping season was 291 mm, 16% below the average of 345 mm. Unfortunately, this was the 3rd consecutive year of below-average rainfall. Rapid rise in temperature coupled with drought at the terminal growth stage of the chickpea crop forced early maturity and reduced productivity.

# Director General's Report

## Major Accomplishments

Years of basic, strategic, and adaptive research on pigeonpea since 1974 at ICRISAT Center bore fruit this year. In July, when the Indian Government authorities released the pigeonpea hybrid ICPH 8 in peninsular India, it became the first pulse hybrid to be released for cultivation anywhere in the world. ICPH 8 yields 30 to 40% more than conventional open-pollinated cultivated varieties.

The hybrid was produced by a breeding procedure that uses genetic male sterility as a building block. To spread the benefits of this new technology a network was established, involving 10 Indian agricultural universities and the Indian Council of Agricultural Research (ICAR). This network is now producing and evaluating new pigeonpea hybrids, and provides the opportunity to breed better hybrids wherever research on pigeonpea improvement is taking place. It is expected that this collaboration within the network will lead to significant increases in pulse production.

Following the release of ICPH 8, we organized a day-long workshop at ICRISAT Center on hybrid pigeonpea seed production technology for 33 enthusiastic representatives of 23 private- and public-sector seed companies.

The technology that developed ICPH 8 is only a beginning. We need to continue our work on pigeonpea hybrids, particularly our attempts to find cytoplasmic male sterility that would facilitate efficient large-scale hybrid production.

**The World's First Hybrid Pigeonpea Reaches Farmers' Fields**

*Roguing to remove fertile plants from female rows in a public-sector seed company's seed-production plot of ICPH 8 at Nandikotkur, Andhra Pradesh, India* (inset: *flower, anthers, seed, and pod of ICPH 8).*

*Scientists from the Sudanese national agricultural research program, and ICRISAT programs in southern and eastern Africa comparing Striga-resistant sorghum variety Mugawim Buda* 2 (left) *and local Striga-susceptible genotype at Sam Sam, Sudan.*

**Two Sfr/ga-resistance Nursery Sorghum Entries Released in Sudan**

Two sorghum genotypes with resistance to *Striga* were released in Sudan this year. These genotypes will be a boon to farmers in that country where the parasitic weed causes serious damage to the sorghum crop. The global losses each year in sorghum production caused by *Striga* are estimated at U.S.$ 764 million. A Strign-resistant variety, SRN 39, sent to the Sudan in 1979 as an entry in an ICRISAT international Striga-resistance nursery was released this year as Mugawim Buda 1. In 1990, about 360 t of its seed, sufficient to sow 36 000 ha, were produced for distribution to farmers. Another line from the same nursery, IS 9830, was also released as a Stign-resistant variety, Mugawim Buda 2.

**Characterization of Agroclimatic Environment of the Semi-arid Tropics**

Rains and temperature are crucial to agriculture throughout the semi-arid tropics (SAT). We are using Arc-Info, a geographic information system (GIS) to help us in the definition of research domains relevant to the SAT. Using GIS, we can overlay maps showing (a) major biotic and abiotic constraints that affect ICRISAT's mandate and other crops, (b) major soils, and (c) climatic variables (e.g., rainfall and temperature) and length of the growing season (LGS). Maps showing the locations of important cropping systems in different agroecological zones within the SAT have been prepared, as have maps showing the extent and distribution of sorghum, pigeonpea, millets, groundnut, and maize. GIS techniques can be used to identify potential areas for cultivation, for instance, those involving new short-duration varieties. This consolidated information is being used to help plan our ongoing research activities.

**ICRISAT Pearl Millet Variety Provides Food Security in Northern Namibia**

This year we were able to contribute to the well-being of farmers and consumers in northern Namibia when seed of high-yielding ICRISAT pearl millet varieties began to reach farmers in significant quantities. The Southern African Development Coordination Conference (SADCC)/ICRISAT Sorghum and Millets Improvement Program (SMIP) increased 10.5 t of Okashana 1 (originally ICTP 8203) seed during the 1990 winter at its off-season location, at Mzarabani, Zimbabwe, and sent it to Namibia where it was sold to farmers.

*Dr Sam Nujoma, and his wife near harvested lieads of pearl millet variety Okashana 1 in Namibia* (left); *A SADCC researcher from Tanzania inspects a seed-multiplication block of Okashana 1 at Mzarabani, Zimbabwe* (right).

During the 1990/91 season, in northern Namibia, 30 t of seed were produced and approximately 20 t sold to 10 000 farmers. The quantity distributed was sufficient to sow some 5 000 ha in 1991/92, a season characterized by severe drought. Nevertheless, our scientists estimate that Okashana 1 doubled the average local pearl millet yields of 200 kg/ha. The resulting 1 000 t of additional grain will contribute over U.S.$ 250 000 to the national economy and improve basic food security in northern Namibia. Further seed multiplication is taking place during the 1991/92 cropping season. If rains are favorable, the resulting seed will contribute over U.S.$ 900 000 worth of additional grain during the 1993 harvest.

The Indian Government's notification of the release of our pearl millet variety ICMV 84400 (MP 155), under the new name ICMV 155, for general cultivation in the country was another achievement for the Institute.

This cultivar is intended to be the successor to ICMV 1 (WC-C75), which has been in cultivation in India since 1982. ICMV 1, an earlier achievement of ICR1SAT and our collaborators, was noted for its resistance to downv mildew *(Sclerospvra graminicola)* disease and for increased yields over previous popular cultivars. It is estimated that ICMV 1 has contributed at least U.S.S 17 million per annum to Indian agriculture in new income streams since 1987.

ICMV 155, in addition to its resistance to downy mildew, consistently yields 12% more grain and 9% more fodder than ICMV 1; the latter statistic is evidence of the importance we give to the livestock feed component of this crop. This year we distributed 57 kg of breeder seed of ICMV 155 to 19 seed-production agencies in India. It is expected to reach farmers in quantities sufficient to sow several thousand hectares in 1992. For the first time in India since the 1960s, farmers have an alternative choice before a widely cultivated pearl millet variety, or one of its parental lines, succumbs to downy mildew.

*Downy mildew resistant pearl millet variety ICMV 155 is expected to be the successor to WC-C75 in India.*

Our efforts to develop sustainable agricultural systems in the harsh environment of Sahelian Africa have met with some success. Eight years of continuous pearl millet cultivation on a typical sandy soil in Sahelian Africa led to serious soil degradation in terms of a decline in soil organic matter, a concomitant decline in cation exchange capacity, and acidification of the soil root profile. Our Sahelian Center scientists found that pearl millet yields steadily declined from about 3 t/ha in 1983 to less than 1 t/ha of total biomass in 1991. Organic amendments appeared to be crucial in maintaining soil productivity and pearl millet yield.

Manure is the most effective amendment, but crop residue combined with the application of phosphorus and nitrogen chemical fertilizers showed almost equal results in building up soil quality. Crop yields in recent years increased and stabilized at about 4 t total biomass per hectare with appropriate amendments.

**Acceptance of Improved Groundnut-production Technologies in India Assessed**

Feedback on the adoption of ICRISAT technology and released varieties is important for us and we are delighted when we receive positive responses. A majority of farmers in the Indian states that grow groundnut appreciate such improved ICRISAT varieties as ICGS 11, ICGS 44, ICGS 21, and ICGS 76. ICG (FDRS) 10 is particularly favored in coastal areas of Andhra Pradesh and Tamil Nadu. Groundnut farmers in these states are adopting ICRISAT's improved production technology with modifications to suit their local needs. Maharashtra, Kamataka, and Tamil Nadu are leading in the technology adoption.

These facts were revealed by the joint evaluation of the acceptance of improved groundnut-production technologies conducted by ICAR in September in collaboration with the Directorate of Oilseeds Development, state cooperative oilseeds growers' federations, agricultural universities, state Departments of Agriculture, and ICRISAT.

**India Joins Asian Grain Legumes Network**

India is now a full member of the Asian Grain Legumes Network (AGLN). The ICRISAT-ICAR Policy Advisory Committee set up a sub-committee in 1991 to review collaborative research projects that will become part of the AGLN. The progress of collaborative groundnut projects was reviewed on 30 November at ICRISAT Center, following the International Groundnut Workshop. A similar review of chickpea and pigeonpea collaborative projects is planned for February 1992.

*The spread of bacterial wilt disease of groundnut in fanners' fields such as this one in Vietnam necessitates changes in research strategies to combat the disease. AGLN helps to coordinate these efforts.*

**Technology Exchange**

During the year, work plans for collaborative research were launched between ICAR and the Cereals and Legumes Asia Network (CLAN)V ICRISAT. A major accomplishment of our AGLN Coordination Unit was to put into full operation the Asian Grain Legumes On-farm Research program in all four project countries (Indonesia, Nepal, Sri Lanka, and Vietnam). The first season's results were encouraging. The staff of the national agricultural research systems (NARSs) are showing considerable interest and commitment in implementing this project.

**Award for Dr Swindale**

This year, my predecessor Dr Leslie D. Swindale, who retired in July, was conferred with the Padma Bhushan, a major civilian award, by the President of India. The distinction honors both the individual and the Institute that he led so effectively for 14 years.

## Genetic Resources Highlights

**Long-term Gene Bank Becomes Operational**

We are fully committed to caring for the future of the genetic resources preserved in our gene bank. During the year, chambers for the long-term storage of mandate crop germplasm became functional and were formally inaugurated on 10 May. After processing, 9 602 germplasm samples to date have been transferred to the chambers for safe preservation for over 50 years as base collections.

With the involvement and partnership of NARS, we evaluated, classified, and selected 2 340 promising germplasm sorghum lines in Sudan, jointly with the International Sorghum/Millet, Collaborative Research Support Program (INTSORMIL) and the Wad Medani Agricultural Research Station; 2 644 finger millet and 250 chickpea lines in Zimbabwe; and 500 groundnut lines in Malawi.

Our joint germplasm evaluation program with ICAR's National Bureau of Plant Genetic Resources (NBPGR) is continuing satisfactorily. A catalog of forage sorghum germplasm was published jointly by NBPGR and ICRISAT this year.

**Germplasm Collection and Distribution**

Several germplasm collection missions were launched this year in India, Namibia, Sri Lanka, and Uganda, in collaboration with NARSs. This effort resulted in the collection of 1840 samples (260 sorghum, 1 003 pearl millet, 124 chickpea, 45 pigeonpea, 186 groundnut, 152 minor millets, and 70 samples of wild relatives of ICRISAT's mandate crops). Among the samples of wild relatives, *Pemiisetum flaccidum* Griseb and *P. foermeranum* Leeke are new species acquired this year. Over 36 thousand germplasm samples of our mandate crops were distributed to scientists for use in crop-improvement efforts at ICRISAT locations (14 386), to other scientists within India (15 357), and elsewhere (6 648).

A Memorandum of Understanding between ICAR and ICRISAT, presently being finalized, will lead to the conservation of a duplicate set of pigeonpea germplasm at the NBPGR gene bank in New Delhi. This is important to ensure the future safety of the germplasm.

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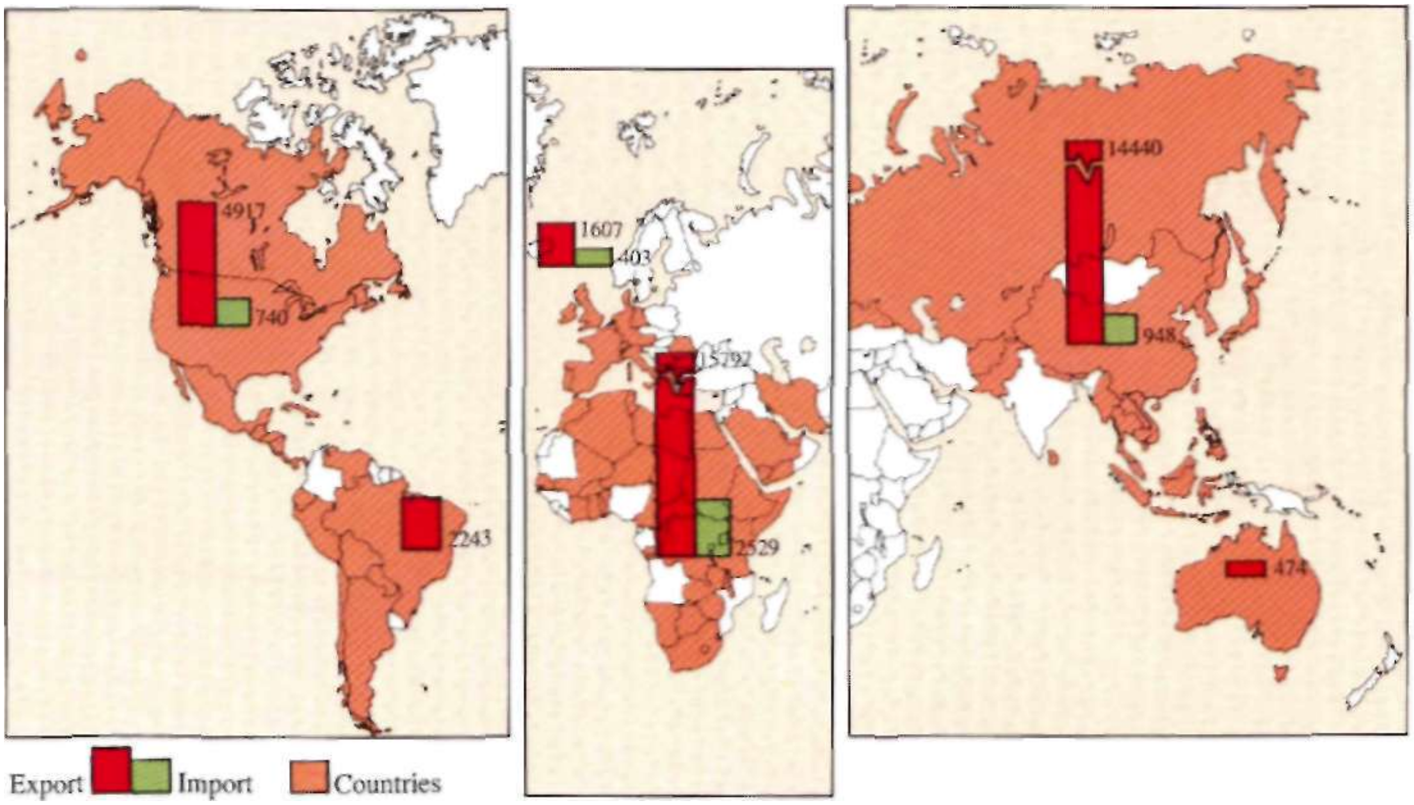
1. The Cereals and Legumes Asia Network (CLAN) was established this year, incorporating the work of ACLN and most of the activities of the Cooperative Cereals Research Network (CCRN). However, for practical reasons in 1991, AGLN and CCRX functioned separately.




### Plant Quarantine Progress

Our Plant Quarantine Unit, a joint endeavor between NBPGR and ICRISAT, is vital to the movement of germplasm between countries. The Unit is responsible for the two-way movement—export and import—of the Institute's seed and plant material. During 1991, the Institute exported over 39 thousand seed samples of its mandate crops to 87 countries. All these samples were processed by this Unit.

ICRISAT imported 4 620 seed samples of its mandate crops from 24 countries. These were examined by the staff of NBPGR, Hyderabad, and seed samples found free from exotic seedborne pathogens were released for their 'grow-out' in the Post-Entry Quarantine Isolation Area at ICRISAT Center for one season. This 'grow-out' serves as an additional check to intercept any exotic pathogen that may have escaped earlier tests.

## Cereals Research Highlights

### Global Impact of Cooperation between ICRISAT and NARS

Participation of the National Research Centre for Sorghum (NRCS) at Rajendranagar, near Hyderabad, and the All India Coordinated Pearl Millet Improvement Project (AICPMIP) in *the* ICRISAT-coordinated Cooperative Cereals Research Network (CCRN) trials is beginning to have a global impact.

Notable among the trial entries in 1991 were two sorghum cultivars contributed by NRCS that are performing well in international trials. Variety CSV 10, bred at Udaipur in Rajasthan, was among the top five entries for grain yield at Samanko (Mali), Shandaweel (Egypt), Suphanburi (Thailand), and Citayam (Indonesia). The other is the sorghum hybrid CSH 9, bred at NRCS, which was among the top five entries at Magdaleno (Venezuela), ICRISAT Center and Surat (India), and Bengou (Niger).

Scientists from these organizations and several state agricultural universities shared equally with those of ICRISAT in CCRN's global research achievements during the year.

**Crop Improvement in the American SAT**

This year we reassessed our responsibilities in the American SAT. The possibility of extending research activities on sorghum, groundnut, and pigeonpea into South America is being investigated. The Comision Latinoamericana de Investigadores en Sorgo (CLAIS) network was enlarged to include South America in addition to Mexico, Central America, and islands of the Caribbean. Consequently, the reorganization of the ICRISAT Latin American Sorghum Improvement Program (LASIP) is progressing satisfactorily. The LASIP Team Leader acts as general network coordinator, with regional coordinators for South and Central America.

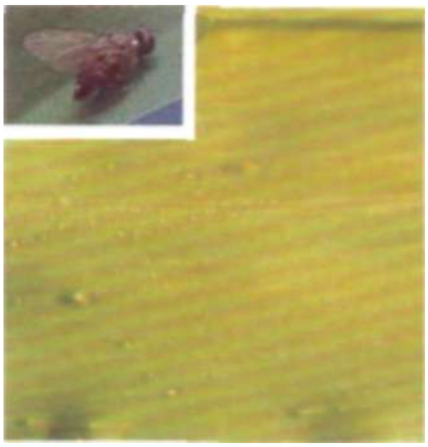
Mozambique Benefits from ICRISAT's Sorghum Research

In Africa, the National Seed Corporation in Mozambique [Sementes de Mocambique (SEMOC)], grew three varieties of sorghum—Macia (from SADCC/ICRISAT SMIP) and SV 2 (from Zimbabwe MARS) on 500 ha in the 1991/92 season, which at a very modest estimate will provide seed for 50 000 ha; and Mamonhe (also from SADCC/ICRISAT SMIP) on 172 ha in the 1990/91 season, in Tete Province and Namialo, providing seed to the farmers to cultivate 17 200 ha. This seed production activity in Mozambique will provide adequate seed quantities for initial distribution to farmers there.

Pearl Millet Variety Released in Burkina Faso

Yet another success in Africa, in cooperation with NARS, was in Burkina Faso where an improved open-pollinated pearl millet variety IKMV 8201, developed by ICRISAT in cooperation with the Institut national d'etudes et de recherches agricoles (INERA), was released for general cultivation and is now being grown by farmers.

Our entomologists, in association with other scientists at ICRISAT Center, demonstrated that susceptibility of sorghum to shoot fly *(Atherigona soccata),* a major pest that causes an estimated U.S.$ 337 million loss in the grain and stover yield per annum, is associated with the accumulation of moisture in the central whorl leaf of seedlings. Leaf wettability was found to be associated with the amount and morphology of surface wax on this leaf, and was reflected in the level of resistance to shoot fly. The trait appears to be genetically controlled. This result of strategic research, it is expected, will contribute substantially to the control of crop losses caused by shoot fly.



*A wet sorghum central leaf whorl.* (Inset) *Adult shoot fly on a sorghum leaf.*

Based on 3 years of national trials, the Commission technique des productions vivrieres et oleagineuses of the Institut d'economie rurale (IER), Mali, recommended three ICRISAT-developed pearl millet varieties for inclusion in the official list of promising varieties. These are KMP 1, IKMP 3 (jointly developed

*Sorghum variety ICSV 247 resists lodging in Nigeria and several diseases in southern Africa.*

with INERA, Burkina Faso), and ICMV-IS 88102. Seed of these varieties will now be multiplied for on-farm tests by extension agencies in Mali. Variety ICMV-IS 88102 gave high and stable yields in the Southern Sudanian and Northern Guinean Zones of Mali and Burkina Faso and was recommended by INERA for on-farm tests.

ICRISAT sorghum variety ICSV 247, which incorporates the delayed senescence (ability to stay green) trait of landrace E-36-1, has been found to be resistant to stalk rot (*Fusarium moniliforme*) and consequently to lodging in multilocational trials in Nigeria. In southern Africa, this open-pollinated variety remained free from infection, under severe natural pressure from such fungal leaf diseases as anthracnose (*Colletotrichum graminicola),* leaf blight *(Exserohilum turcicum),* sooty stripe *(Ramulispora sorghi),* and rust *(Puccinia purpurea).* National programs in Zambia and Zimbabwe have incorporated this source of resistance into their sorghum breeding projects.

Further screening of sorghum for resistance to head bugs (*Eurystylus immaculatus)* confirmed the resistance of Malisor 84-7, a product of the ICRISAT-Mali Bilateral Program in cooperation with IER. Under artificial infestation, 56 head bugs in every 2 panicles were recorded for Malisor 84-7 compared to 1323 head bugs on line 89926-1. Our scientists in Nigeria also reconfirmed the resistance of Malisor 84-7 to head bugs. Quality tests, measured after artificial infestation, showed that Malisor 84-7 is superior in dehulling recovery rate, and has good *id* (an important food product) quality compared to susceptible trial entries.

### Other Successes in Cereals

In India, ICRISAT sorghum variety ICSV 745 adopted for cultivation by farmers in Karnataka a few years ago, continues to show resistance to midge (*Contarinia sorghicola*), an insect pest which feeds on the developing grain.

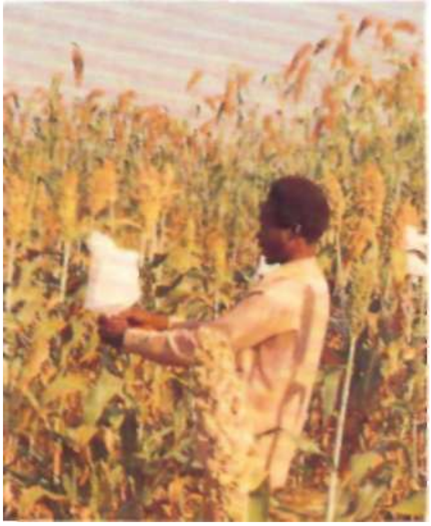
*ICRISAT-developed midge-resistant sorghum variety ICSV 45 is popular with fanners in Dharwead, Karnataka state, India.*

Research showed that resistance is necessary in both male and female parental lines to produce a resistant sorghum hybrid. Resistance was introduced into female-sterile lines in the mid-1980s. At ICRISAT Center, midge resistance has now been successfully introduced into male-sterile lines, which will lead to production of midge-resistant hybrids.

In Nigeria, hybrid sorghum yields were again encouraging with many entries yielding over 6 t/ha compared to control variety yields of 4.03 t/ha (Samsorg 3) and 2.4 t/ha (Gaya Early). ICSH 89002 NG confirmed its high yield level of 1990 and gave the highest grain yield of 3.71 t/ha over eight locations in western Africa. Pioneer Hybred Seed (Nigeria) Ltd. began experimental production of ICSH 89002 NG and ICSH 89001 NG on their farms.

The association of flavan-4-ols, polyphenolic compounds, with mold resistance in colored sorghum grains has been established by our biochemists at ICRISAT Center. (See *Crop Utilization* section of this publication for details.)

We regularly assist national agricultural programs to improve our mandate crops in southern Africa. The national program breeders of sorghum, pearl millet, and finger millet in Zambia have developed varieties that have been released in their country following assistance from SADCC/ICRISAT SMIP in the regional evaluation of these varieties, in screening them for disease and insect resistance, and in the evaluation of quality traits. During the 1990/91 season, in collaboration with extension agencies and Sasakawa Global 2000, some 10 000 farmers grew the white-grained sorghum variety Kuyuma, and over 4 000 farmers, the red-grained hybrid MMSH 413. Some 400 farmers grew the recently released ICRISAT pearl millet variety, Kaufela (ICMV 82132), and 40 farmers grew the released ICRISAT finger millet variety, Lima (IE 2929). Approximately 40 t of seed of Kuyuma were



*An IER technician examining sorghum panicles for head bugs at Sotuba, Mali.*

*Breeders from national programs and the SADCC/ICRISAT Sorghum and Millets Improvement Program jointly evaluating sorghum in regional trials at Golden Valley, Zambia.*

produced during the 1991 winter season and provided to Zamseed, the national seed company, for sale to farmers.

In cooperation with the Department of Research and Specialist Services and the extension agency, Agritex, in Zimbabwe, 160 farmers in the dry southern part of the country grew three pearl millet varieties. Among the three, SDMV 89004 was much appreciated, yielding almost twice as much as the local variety. SDMV 89004, developed from the SADCC Medium Maturing Composite and widely tested across the SADCC region since the 1987/88 season, is scheduled for release to farmers in Zimbabwe in 1992 as PMV 2. Seed of the variety is being multiplied.

**ICRISAT Sorghum Identified for Malting in Nigeria**

Sorghum grain and malt are being extensively used in Nigeria to manufacture several food products and beverages. ICRISAT cooperated with the major companies producing such products in Nigeria by supplying them with bulk samples of grain for analysis. As a result, a high-yielding, early-maturing cultivar, ICSV 400, has been identified as a good candidate for malting. (See *Crop Utilization* section for details.)

**Pearl Millet Research on Downy Mildew**

Our pathologists demonstrated that five highly inbred pearl millet genotypes (IP 18292, IP 18293, IP 18294, IP 18296, and IP 18298) selected for their morphological marker traits, are highly resistant to infection by the downy mildew pathogen. These genotypes were found to remain free from infection under severe disease pressure at ICRISAT Center, Mysore, and Aurangabad in India. They also remained free from the infection in Cinzana, Mali, and Bengou, Niger. The mechanisms of resistance to infection and inheritance of resistance are being studied in an attempt to introduce high degrees of resistance to downy mildew into breeding lines.

Studies on resistance to downy mildew in hybrids indicated that inbred lines differ in their combining ability for resistance to other diseases. The male-sterile line ICMA 88004 and pollinators IPC 736 (ICMP 85410) and IPC 90008 (BSEC TCP2 C2) have the greatest ability to confer downy mildew resistance to their hybrid offspring. These parents can be effectively used to breed downy mildew resistant hybrids.

**Trap Developed to Control Pearl Millet Stem Borer in Farmers' Fields**

Among the insect pests that attack pearl millet in western Africa, the stem borer, *Coniesta (=Acigona) ignefusalis,* causes a loss of U.S.$ 100 million in grain yield per annum in Burkina Faso, Niger, and Nigeria, three of the main pearl millet producing countries in western Africa. Cultural techniques, insecticides, resistant varieties, and natural enemies have been tested as means to reduce pest damage without much success. Recent research at the ICRISAT Sahelian Center (ISC) in collaboration with Natural Resources Institute (NRI), Overseas Development Administration, UK, on pearl millet stem borer pheromones has produced a cost-effective and environmentally safe trap that could eventually be used in farmers' fields as a control strategy. Discussions to involve NARSs in further research on this innovation are scheduled for 1992.

*Catches of male stem borer moths in a water-oil trap developed at the ICRISAT Sahelian Center.*

Pheromones are nontoxic, species-specific sex-attractants and can be used in the control of insect pests, for example, by confusing the males, thus reducing the probability of successful matings. The collaborative research on the pearl millet stem borer focused on field experiments to optimize the attractive pheromone blend, to evaluate the efficacy and longevity of the pheromone when dispensed from new polythene vials, and to identify a suitable trap design.

All these objectives have been achieved. A highly efficient pheromone blend has been synthesized and a controlled-release device that protects the blend from environmental degradation with effective release, for as long as 28 days, has also been developed.

Traditional pheromone traps are not readily accessible to farmers. Our entomologist at ISC has developed a water-oil trap from local materials, which proved to be efficient and consistent over time compared to the popular sticky-board trap. For example, in two separate experiments, the pheromone-baited water-oil trap caught 1 000 and 2 800 male moths compared to only 16 and 210 by the pheromone-baited sticky trap. Data for each of these experiments are based on 18 trap nights.

This collaborative strategic research has several immediate applications: it is useful in large-scale monitoring for stem borer population, distribution, and migration studies; is cost-effective and easily available to farmers; and is a highly desirable, environmentally safe component in the management of the pearl millet stem borer in farmers' fields.

*Larva of pearl millel stem borer* (inset) *and the damage it causes to crops.*

Our responsibilities in Asia increased when we were requested this year to organize and help coordinate two new research networks. Firstly, participants at a Rockefeller Foundation Conference, held 6-10 May to review research on biotechnological methods to improve sorghum and pearl millet breeding, recommended that ICRISAT take the lead in coordinating research on the molecular genetics of these two cereals. This informal network would make rapid progress possible in constructing restricted fragment length polymorphism (RFLP) maps or deoxyribonucleic acid (DMA) markers of sorghum and pearl millet. Cooperation of molecular biologists and breeders in the network allows for tagging of morphological and other traits useful in breeding with RFLPs and other molecular markers. Consequently, this would improve selection efficiency.

Then, administrators of national programs in Asia recommended, during a workshop organized by CCRN, that a research network be established at ICRISAT Center to coordinate strategic and applied research on sorghum in the region. It was further noted that several national programs in the Asian region are capable of assuming responsibility for regional research. Our Cereals Program is consequently expanding its activities in Asia through cooperative research projects with NARSs.

## Legumes Research Highlights

### Successes in Chickpea Breeding

Research on legumes at various ICRISAT locations also made impressive progress, especially in chickpea. Six kabuli chickpea lines developed by the ICR1SAT/ICARDA Chickpea Project were selected from international trials and released as cultivars this year: Ghab 3 in Syria, Akcin in Turkey, FLIP 84-79C and FLIP 84-92C in Algeria, ILC 482 and ILC 3279 in Iraq, FLIP 84-79C and FLIP 84-92C in Tunisia, and FLIP 84-92C in Morocco. From the cooperative efforts of the two international agricultural research centers, by the end of 1991, over 24 kabuli chickpeas had been released in 16 countries under 41 names.

*Scientists from West Asia assessing winter-sown chickpea at Ghab Station, Syria.*

**Shortest-duration Chickpea Variety Released in Maharashtra, India**

Our chickpea breeders were encouraged by the release of the shortest-duration kabuli variety 1CCV 2 in the Indian state of Maharashtra. As it matures early, the variety escapes drought in later stages of growth. ICCV 2 was earlier released in Andhra Pradesh state. Further, ICRISAT's desi variety ICCV 10 progressed to a stage ready for release in India.

In research on chickpea crop improvement, genotypes selected for their superior root traits demonstrated their potential to yield well, even under terminal drought stress conditions.

**Winter-sown Chickpeas Acceptable to Farmers in West Asia and Northern Africa**

After 13 years of intensive research, farmers in West Asia and northern Africa (WANA) have begun adopting winter-sown chickpeas. These chickpeas were estimated to have been sown on over 50 000 ha during the 1990/91 winter. Winter-sown chickpeas produce a minimum of 50% to a maximum of over 100% more yield than traditional spring-sown chickpeas in the WANA region.

**Progress in Pigeonpea Production in Sri Lanka**

There has been good progress in the Pigeonpea Production Project in Sri Lanka where we jointly collaborate with the Asian Development Bank and the Department of Agriculture, Sri Lanka, to improve the crop production. An indication of this was apparent when the Sri Lankan Minister for Agriculture encouraged the Project to consider achieving a dramatic increase in sown area (from 70 ha to 4000 ha). As this was not immediately realizable because of a shortage of seed, the actual increase was a modest 200 ha, sufficient to allow an orderly establishment of plots and of dhal-processing facilities. The production system appears to be economically very attractive. The ICRISAT line ICPL 84045 was identified as a replacement for ICPL 2 in Sri Lanka. A video made by a Sri Lankan company on this Project is nearing completion.

*Harvesting pigeonpea at a research station at Malta Illuppallama, Sri Lanka.*

**Stable Hybridoma Clones Specific to Bud Necrosis Virus Identified**

Most plant viruses cause yield loss in crops. Our virologists found that the virus that causes bud necrosis disease in groundnut is a distinct member of the tomato spotted will virus group, and therefore named the virus, bud necrosis virus (BNV). It has been shown to be transmitted mainly by an insect, *Thrips palmi,* and various aspects of virus/vector relationships have been determined. In laboratory and field tests, groundnuts with additional sources of resistance to BNV with high yield potential have been identified.

A laboratory to produce monoclonal antibodies was established at ICRISAT Center during the year, and many stable hybridoma clones (monoclonal antibodies) specific to BNV were identified. This is the first time that this technology using monoclonal antibodies has been used at ICRISAT. We can now provide training to NAKS scientists in the production of monoclonal antibodies and highly specific diagnostic tools for virus identification.

Source of Resistance to Groundnut Rosette Virus Identified

Resistance to groundnut rosette virus (GRV) has been identified among derivatives of wild *Arachis* species produced by our Cell Biology Unit at ICRISAT Center. A selection from these interspecific hybrids was the only line in over a thousand entries, including cultivated genotypes, to show resistance to GRV at the SADCC/ICRISAT Groundnut Project in Malawi. This is the first time resistance to rosette virus disease has been found in a non-western African groundnut genotype. The resistant genotype is being used in SADCC/ICRISATs breeding program in Malawi as a source of rosette resistance.

In collaboration with the Institut de recherches pour les huiles et oleagineux (France), INERA (Burkina Faso), and IER (Mali), we carried out a survey on groundnut viruses in Burkina Faso and Mali where groundnut rosette and peanut clump viruses were found to be common. Samples were sent for

*Plants infected by the chickpea chlorotic dwarf virus have brown and yellow leaves.*

electronmicroscopy studies to the Centre de cooperation internationale en recherche agronomique pour le developpement (CIRAD), France. During the survey it was noted that the incidence of viruses was lower in farmers' fields than on research stations.

A widely distributed geminivirus has been isolated from chickpeas. The virus, referred to as chickpea chlorotic dwarf virus, has been characterized, and detection methods developed. It will be the first record from Asia of a leafhopper-transmitted geminivirus in dicotyledons or broad-leaved plants. The symptoms produced by this virus are similar to chickpea stunt disease, the most important virus disease of this crop, and it has been detected in the states of Gujarat, Madhya Pradesh, Andhra Pradesh, Haryana, and Rajasthan in India and in Pakistan. Although the incidence of the virus is not high, its potential to reach high levels was shown in some of the breeding material. ICRISAT can now provide efficient tools to screen genotypes for resistance to the virus.

In collaboration with NARS scientists, our legume pathologists identified pigeonpea lines with resistance to sterility mosaic disease in India. They found that these lines were also resistant to the disease in Nepal. Similar spinoffs in our efforts to establish stability of resistance were shown in lines originally found resistant to fusarium wilt (*Fusarium udum*) in India, which were later found resistant to this disease in Kenya and Malawi.

**Groundnut Releases in India**

Our groundnut scientists were encouraged by the release in India of ICGV 86590, a variety that is resistant to several diseases and insect pests. Further, 'Konkan Gaurav[7] was selected from ICGS 1 by the groundnut breeder at the Konkan Krishi Vidyapeeth (University) in Ratnagiri, Maharashtra state, and released for cultivation in that state.

Over 6 t of breeder seed of ICRISAT groundnut varieties were supplied by our scientists to 12 public-sector, seed-producing agencies, 6 research stations, 27 private seed companies, and 251 farmers. This material is sufficient to sow 36 ha of seed-multiplication plots, which in turn could provide seed for 432 ha in the next season, increasing the available seed sufficiently to sow 12 times the area sown in the previous season.

*An ICRISAT/NRI scientist examines* Helicoverpa *lanvl development.* (Inset) Helicoverpa armigera *larvae in culture.*

Wild *Arachis* species representing six sections of the genus have been analyzed for their chemical composition and protease inhibitors. Some wild species' seeds contained more than 60% oil. Several wild *Arachis* species are potential sources of quality attributes and can be used in breeding programs.

Scientists at ICRISAT Center established that $^{13}C$ discrimination and leaf thickness are good indicators of water-use efficiency in groundnut and can be used for drought-screening traits.

In collaboration with NRI, an insecticide-resistance testing laboratory has been established at ICRISAT Center and methodologies put into practice to monitor insecticide resistance in the major lepidopteran pests of legumes in India. Representatives of the International Organization on Pest Resistance Management and ICAR visited the new facilities. These visitors later proposed that the facility should become a key location for insecticide-resistance monitoring and training within India.

**Pigeonpea *Dhal* that Cooks Rapidly Developed**

We studied methods to develop pigeonpea *dhal* that cooked rapidly. A pectinase enzyme treatment appears to have good potential to develop pigeonpea *dhal* that cooks faster and has better consumer acceptability than nontreated *dhals.* If such *dhal* were to become popular there would be considerable domestic energy savings. Collaborative studies are being followed up with Indian NARS. (See *Crop Utilization* section for details.)

The physico-chemical properties of grain legumes are important in the development of food products, and in the evaluation of their quality. Procedures to evaluate such functional properties as water and oil absorption, emulsification capacity, gel consistency, viscosity, swelling power, solubility, and gelation capacity have been standardized. The emulsification capacity (which affects the shelf-life of food products) was significantly higher in desi chickpea types than in kabuli types. This year we found that peak viscosity, a direct index of starch viscosity, was positively correlated with gel spread.

The 2nd International Groundnut Workshop, which was jointly sponsored by ICRISAT, the Peanut Collaborative Research Support Program (USA), and CIRAD, was held from 25-29 November at ICRISAT Center. Research progress since the first workshop held in 1980 was reviewed and constraints to production in the various groundnut-producing regions of the world discussed. The workshop provided guidelines for international research and development for the next decade. Reports from donors, special research topics, and concurrent discussion sessions were included in the program, and participants visited our fields and laboratories.

*Participants of the 2nd International Groundnut Workshop viewing farm implements developed at ICRISAT Center.*

## Resource Management Research Highlights

**Relay Cropping Best Suited to Early Rains in Sahelian Africa**

Managing scarce resources is fundamental to progress in agriculture in the SAT. Field studies conducted at our Sahelian Center from 1989 to 1991 showed that when the onset of rains is early, growing a relay crop of pearl millet and cowpea for hay is a better strategy than growing an intercrop of pearl millet and cowpea, in terms of yield. Yield advantages of the relay crop ranged from 28% in 1989 to 54% in 1991. The relay crop also provides ground cover for a longer duration and in comparison to the intercrop is more effective in conservation of soil moisture. Our studies at Tara in southern Niger also showed that relay cropping offers a distinct advantage when the onset of rains is early. We will continue our studies at Tara to further evaluate the yield stability in relay cropping with the early and regular onset of rains.

**Efforts to Predict Disease Epidemics by Understanding Effects of Weather on Groundnut**

We found that the presence of water on groundnut leaf surfaces is a requirement for infection by late leaf spot disease caused by the fungus *Phaeoisariopsis personala.* We have demonstrated a substantial increase in the

*Dew chamber studies on the association of groundnut leaf wetness* (inset) *and the development of foliar diseases.*

infection efficiency when leaves are subjected to alternative wet and dry cycles, compared to continuous leaf wetness.

Since patterns of leaf wetness are important in the development of disease epidemics, we are examining ways to estimate leaf wetness from other meteorological variables. We have found that diurnal changes in the dew-point temperature are unexpectedly large at ICRISAT Center, and have developed a method to simulate hourly dew-point temperature and humidity values. The method uses two spot readings of relative humidity that are routinely measured on meteorological sites in India. It appears likely that it will be possible to use the simulated hourly humidity values to estimate daily wetness periods on vegetation. We have established quantitative relationships between temperature and the latent periods of rust (*Puccinia arachidis),* late leaf spot, and early leaf spot (*Cercospora arachidicola)* diseases of groundnut. Estimation of leaf-wetness periods and information on how they affect disease development, will provide the basis for a scheme to predict epidemics. Such predictions could be used as an aid in resistance sceening or as a basis for extension workers to advise on the application of disease-control measures. We need to assess the potential value of advisory schemes on the time of spraying in areas of contrasting groundnut productivity.

**Effect of Water Erosion on the Productivity of an Alfisol**

Our studies to quantify the relationship between erosion and crop production are yielding good results. Following sorghum, we grew groundnut variety ICGV 86699 on an Alfisol at ICRISAT Center that had different levels of erosion simulated either by scraping known depths of soil to increase erosion or by protecting the surface with plastic nets to reduce natural rates of erosion. Groundnut pod yield decreased from 1.5 t/ha on fertilized plots that had 13 t/ha of soil removed by natural erosion to 1.1 t/ha on plots that had lost 27 t/ha soil in the previous 3 years. For the same plots, the above-ground biomass decreased from 4.2 t/ha to 3.5 t/ha. On the nonfertilized, naturally eroded plots, pod yield did not decrease very much between the two erosion levels. There was no significant effect of desurfacing on the development of crop cover. We have established a power functional relationship between the above-ground dry biomass and the total quantity of soil lost through erosion.

**Research on Conservation Effects of Porous and Vegetative Barriers Continue**

Barriers of plants or porous materials are being investigated at ICRISAT Center as an alternative to bunds for reducing erosion caused by rain. Barriers being investigated are vetiver grass, lemon grass, and stone bunds; runoff and loss of soil from land contained by these are being compared with that from bare soil in standard runoff plots (22-m long) and with two different slopes (0.6 and 2.8%). Early results indicate that the porous barriers are reducing soil loss, because of a reduced sediment concentration early in the season and reduced volume of runoff later. The reasons for these different mechanisms will be investigated.

**Determinate Pigeonpea Genotypes Intercropped with Upland Rice Give Higher Yields than Sole Crops of Rice**

Intercropping upland rice with grain legumes can increase total grain production by 60-80% over sole rice. Pigeonpea was found to be the best companion crop in terms of biomass and crop value. Compared with sole rice, the yield of intercropped rice increased when grown with determinate pigeonpea genotypes because the competition for sunlight was minimized.

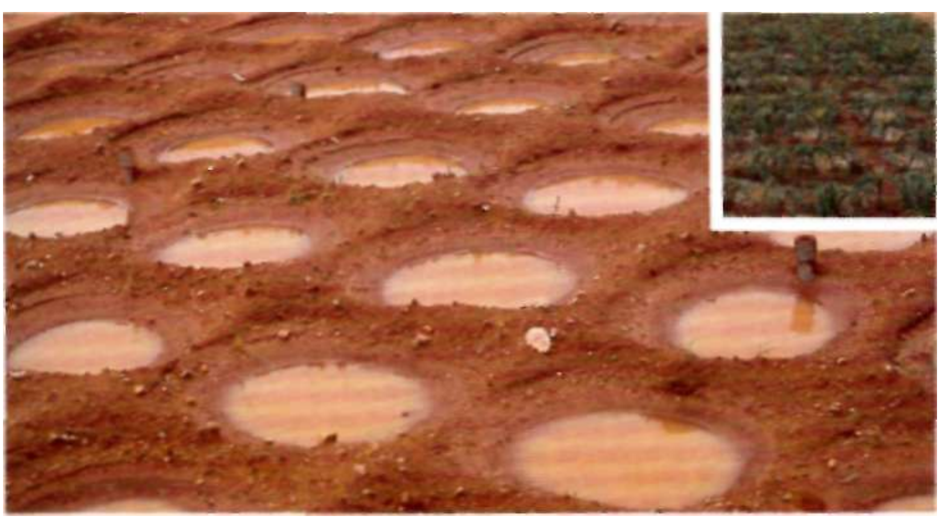
*Studies on the use of vetiver grass* (foreground, inset), *lemon grass, and stone bunds to reduce soil erosion caused by rain.*

The canopy structure of pigeonpea has more influence on the system than differences in phenology among pigeonpea genotypes. Another factor that appears to determine competitive ability is the relative heights of intercropped pigeonpea and rice, since rice is very sensitive to shading, particularly during the reproductive phase.

**Surface Roughness Helps Conservation on an Alfisol**

Various measures associated with excess runoff that help to increase infiltration on soils have been investigated throughout the SAT. One method that has often been tried is 'tied-ridges', in which earthen barriers are placed across furrows between ridges so that water cannot escape as runoff.

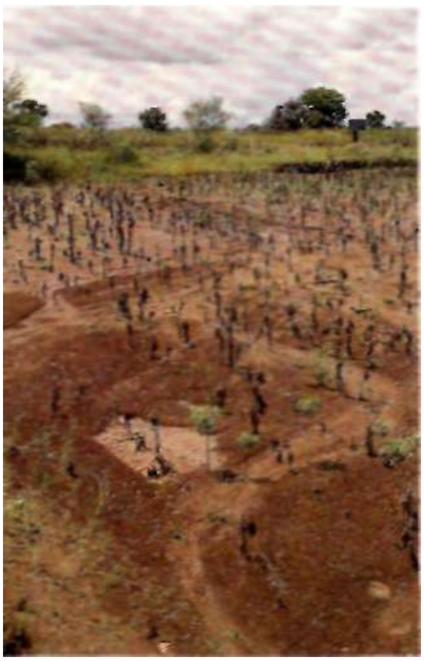
Measurements taken over 4 years (1988-91) during experiments conducted



*Scoops reduced runoff and soil loss and increased pearl millet* (inset) *yields on flat lands.*

under both simulated and natural rainfall at ICRISAT Center indicate that:

- Because of surface crusting and sealing during the early part of the cropping season a good proportion of the rain that falls on Alfisols is lost as runoff. 'Scoops', or shallow pits made in the soil, store most of the rain in depressions. Scoops and tied ridges significantly reduce runoff and soil loss compared to flat land cultivation. Using runoff and soil loss from the flat cultivation as a basis for comparison, scoops on average reduced seasonal runoff (1988-91) by 67% and soil loss by 56%. Runoff in a tied-ridge system was reduced by 33% and soil loss by 27%.
- In both 1990 and 1991, scoops of 5 L capacity (4 scoops/$m^2$) significantly increased the yield of pearl millet over flat cultivation. However, scoops with 2.5 L capacity (4 scoops/$m^2$) gave a difference in crop yield over flat land only in 1990.
- Scoops were found to be more effective in reducing runoff and soil loss than tied ridges. It was observed that the scoops were relatively more stable than the tied ridges, particularly during high-intensity rainfall and runoff conditions. Between 1988 and 1991, scoops breached on significantly fewer occasions than did tied ridges.
- Throughout the rainy seasons of 1990 and 1991, the penetration resistance and bulk density of the top 10 cm soil layer were significantly lower in the scoops than in the flat lands. Even around the harvest period, when the soil was very dry, the bulk density and penetration resistances of 0-10 cm depth were significantly lower in scoops than in the flat treatments.



The *effects of erosion and runoff in a sunflower field, where ICRISAT's improved watershed technology on Vertisols has not been adopted, Chevella village, Andhra Pradesh, India.*

During 1982 and 1983, ICRISAT and the Central Research Institute for Dryland Agriculture (CRIDA) jointly initiated integrated watershed development work at Chevella (Andhra Pradesh) and Mittemari (Karnataka). A base-line survey in these areas was conducted at the beginning of the project. For the initial 3-4 years, the project was closely supervised by research scientists and state extension officials. The adoption of the watershed technology was impressive in the beginiiing when it was closely supervised. Economists working at ICRISAT Center and CRIDA revisited the watersheds in 1991 to assess the impact of the technology on Vertisols and Alfisols after supervision had been withdrawn.

The joint analysis indicates that this technology has been partially adopted by farmers. Many reverted to traditional practices because some of the components of the technological package, such as use of machinery, the broadbed-and-furrow cultivation technique, and fertilizer application were not practical. The impact of this watershed technology is not visible in the short run. Institutional factors, e.g., property rights, social customs, and traditional norms, are important considerations that influence the adoption of this technology. However, watershed technology has helped to improve the overall socioeconomic conditions of the people, but the technology needs to be promoted through the active involvement of the local people at all stages of the project.

**Improved Practices Quadruple Sorghum Yield in Garosso, Mali**

Our economist and agronomist based in Mali conducted on-farm trials in villages using eight households per village. Three improved sorghum cultivars and a local cultivar were compared under traditional and improved practices along with groundnut as an intercrop. Improved farm practices were found to quadruple the sorghum yield in Garosso.

Farmers were asked to rank the varieties by overall agronomic performance and they ranked CSM 388 first. Women fanners were asked to rank the varieties by quality factors (ease of dehulling, high endosperm recovery, ease of pounding, cooking duration, and the taste and keeping quality of *to).* Women farmers also ranked CSM 388 first among the sorghums.

**ICRISAT Sorghum Hybrid Gives Highest Grain Yields in Plant Density and Nitrogen Level Trials in Nigeria**

In Nigeria, we continued joint trials with the Institute for Agricultural Research to evaluate improved sorghum hybrids and varieties under varying plant densities and nitrogen levels in the Sahelian, Sudanian, and Northern Guinean agroclimatic zones. The ICRISAT hybrid ICSH 89009 NG produced, on average, the highest grain yields (4.98 t/ha at Bagauda) at an optimal plant population of 10.6 plants/$m^2$ and with 90 kg of N/ha.

**Technological Change and Equity is Marked in Villages with Assured Rainfall and Well-developed Infrastructure**

Indian village-level studies data gathered by ICRISAT clearly indicate that the real income of the farming communities at Mahbubnagar in Andhra Pradesh, Solapur and Akola in Maharashtra, and Sabarkantha in Gujarat, has increased over time, and that the extent of poverty has declined. Some technological changes have taken place in these villages. We analyzed the village-level studies data from eight villages in these four locations representing contrasting agroclimatic zones of India's SAT to ascertain the impact of new technology on income distribution.

The analyses indicate that the rate of technological change has been faster in those villages with assured rainfall and well-developed infrastructure than in other villages. The real mean income has increased more over time in well-endowed villages than in less-endowed villages. The regional disparities resulting from the introduction of new technologies are partly because of geographic conditions and development of infrastructure. Income is more equitably distributed in those villages where the mean level of income was initially low than in those where it was high.

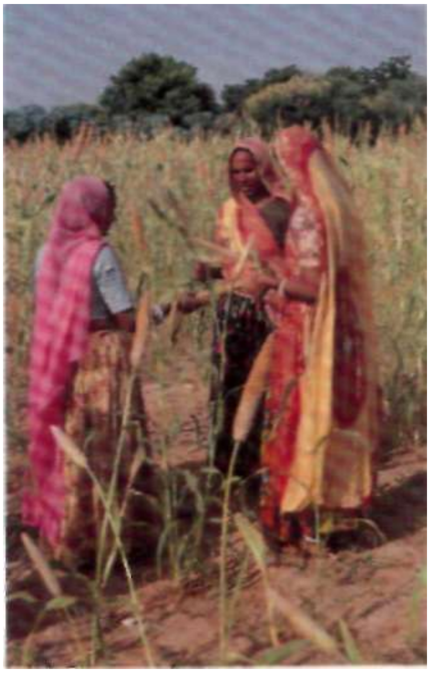
Most of the income gains came from increase in revenue from the sale of crops. Increased income from regular employment was also important. Although most of the households have gained from technological progress, those in the high- and low-income groups gained relatively more than those in the middle.

Studies of soil degradation commenced this year at ICRISAT Center following a recommendation by our latest External Program Review (EPR). The EPR panel members were especially anxious that we should focus on the insidious forms of degradation that are difficult to detect or correct, but could cause severe deterioration of soil and perhaps permanently reduce its potential productivity.

Provision of a Special Environmental Grant from the Australian International Development Assistance Bureau (AIDAB) enabled the initiation of a preliminary survey of soil degradation to be conducted in India. During this survey, we visited major institutions and inspected Alfisols with two consultants from Australia. The aim was to identify the major forms of degradation and to quantify their extent. Only subjective qualitative judgements could be given. Nevertheless, the consultants confirmed the current view that water erosion is the main form of degradation, and that it is sufficiently serious to merit further substantive research. They suggested areas for future collaborative research. Their report is currently being

*Water erosion is the main type of soil degradation on Alfisols.*

studied by several ICAR bodies, the National Wasteland Development Board (India), and ICRISAT scientists.



In collaboration with the International Livestock Centre for Africa (ILCA) and the International Board for Soil Research and Management (IBSRAM), we are conducting research on farms in Ethiopia to develop strategies and technology options to raise and sustain crop and livestock production on Vertisols. Our observations to date indicate that Vertisol fields generally have several microdepressions that exacerbate the waterlogging problem. The observations at Debre Zeit and Ginchi have shown that wheat yields per unit area were 58% to 75% lower in depressed areas (maximum depth 15 cm) than in the smooth portions of the fields. The positive effect of broadbed-and-furrow treatments on wheat yields was observed only in the smooth portions of the field and not in the microdepressions. Land smoothing is obviously a crucial operation that is necessary if the drainage on these soils is to be improved.

Women provide much of the labor for crop production. Their contributions to household activities are also important. Their active participation in the developmental process has not been fully recognized. A comparative study of central peninsular India and northern Cameroon was undertaken to document the role of women in various farm and household activities. On average, women spend more time on farm and household activities than men, but they receive lower wages and have fewer opportunities for outside employment than men. In northern Cameroon, rural women were found to make more farm decisions than in central peninsular India. The study noted that women are generally less well educated than men, a factor that influences their decisionmaking abilities.

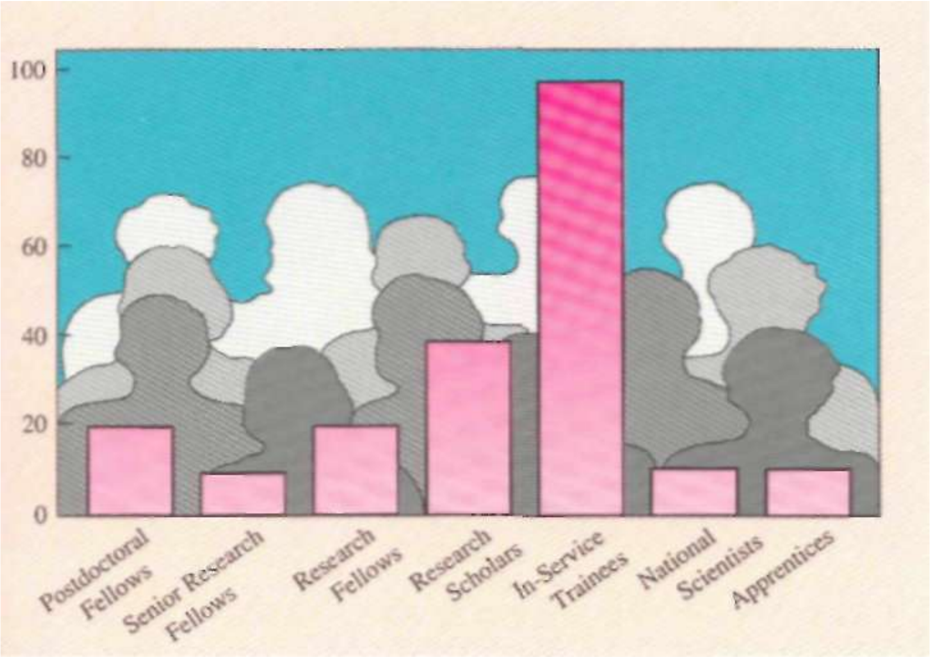
## Human Resource Development Achievements

Each year Ministries of Agriculture, universities, and SAT research and development programs nominate persons for skill-development programs at major ICRISAT locations. Some are accepted, some are not. This year 47 women and 147 men from 47 countries participated in human resource development study programs at ICRISAT Center. They included 19 Postdoctoral Fellows, 9 Senior Research Fellows, 19 Research Fellows, 37 Research Scholars, 93 In-Service participants, 7 national scientists, and 10 Apprentices. These individuals developed their skills in all the major programs at the Center. Excluding the Apprentices, 61% of all other participants were supported from our core budget.

To encourage participation of senior-level scientists with more than 7 years of postdoctoral service from NARS in the SAT, a new category of 'Senior Research Fellow' has been established. Nine senior scientists from five countries took advantage of 132 weeks of collaboration and study in this new program.

Eight Research Scholars from seven countries began their Ph.D. thesis research at ICRISAT Center. Similarly, seven Research Scholars from three countries initiated their M.Sc. thesis research. Eight Ph.D. scholars and two M.Sc. scholars completed their thesis research studies.

There were 19 Postdoctoral Fellows from eight countries. These included, for




*Human Resource Development Program participants at ICRISAT Center, 1991.*



the first time, five Postdoctoral Fellows sponsored and deputed by ICAR, to strengthen the collaborative activities with Indian scientists.

As a follow-up and evaluation effort, we contacted 1 217 earlier participants from 72 countries. Two-hundred and ten from 43 countries responded and were provided with ICRISAT publications and materials.

One in every five participants (excluding those from ICRISAT) of the International Groundnut Workshop held at ICRISAT Center from 25 to 29 November was an earlier beneficiary of our study programs, reflecting the benefits of technology exchange NARSs derive from ICRISAT's Human Resource Development Program.

## Providing Practical Experience in Southern Africa

During the 1990/91 and 1991/92 seasons, the SADCC/ICRISAT SMIP accepted 10 students from the University of Zimbabwe for practical experience during their 3-month summer vacation. This had proved to be a valuable experience for students during 3 earlier years and for the Program staff as well. In 1991, the SADCC/ICRISAT SMIP has had three interns from the *Bulawayo Polytechnic* in Food Technology, and two research interns in economics, one in sorghum breeding, one in forages, one in agronomy, and one in pathology.

Short-term training is also important; 22 individuals from SADCC countries participated in the 6-month training program at ICRISAT Center, 12 of whom were sponsored by the SADCC/ICRISAT SMIP.

Important in this area during the year has been the contribution of the SADCC/ICRISAT SMII's Station Development and Management Officer in northern Namibia. The Government of Namibia provided a resource of Rand 4 million (U.S.$ 1.6 million) to recondition three stations damaged during the

*Learning to produce hybrid sorghum seed at Bagauda, Nigeria.*

war years. These funds were also used to support operations initiating a pearl millet improvement program and the increase of seed.

Apart from the human resource development programs within the region, some training programs for SADCC/ICRISAT SMIP participants are also conducted in USA and Brazil through INTSORMIL, and in Canada through the Canadian International Development Agency.

### Learning to Produce Sorghum Hybrids in Western Africa

A bilingual practical training course on sorghum hybrid seed production was conducted at Bagauda, Nigeria, for 10 participants from Benin, Burkina Faso, Ghana, Mali, Niger, and Nigeria. The course was funded by the Semi-Arid Food Grain Research and Development (SAFGRAD) program, Sasakawa Global 2000, and iCRISAT. ICRISAT and the national programs of Cameroon, Niger, and Nigeria provided the resource persons.

## Other Highlights

### Legume Research in Africa Gets a Boost

Legume research in Africa received a major boost when a research proposal to strengthen the pigeonpea component of the Eastern Africa Regional Cereals and Legumes (EARCAL) progam was approved for funding by the African Development Bank. Subsequently, ICRISAT has appointed an agronomist in Kenya and a breeder in Malawi to work on the crop.

### Facilities at Samanko Inaugurated

ICRISAT's West African Sorghum Improvement Program (WASIP) Mali building complex was completed and occupied early in the year. It was inaugurated at Samanko on 14 February by the Malian Minister of Agriculture, Mr Moulaye Mohamed Haidara. The land was donated by the Government of Mali and funds were provided by the United States Agency for International Development (USAID), CIRAD, and ICRISAT. At a social function later, the researchers of Mali presented Dr Swindale, with a golden *Ciwara* (Great Cultivator) in recognition of his services to ICRISAT and Mali.

The ICRISAT-Mali Bilateral Program terminated in May and the Minister for Rural Development, Madame Sy Maimouna Ba, conveyed her Government's gratitude to ICRISAT for its contribution to Malian agriculture. The achievements were further endorsed by USAID, who had funded it for 12 years. Final reports, in English and French, have been produced.

ICRISAT-Mali Bilateral Program Terminated

A Memorandum of Understanding (MOU) between ICRISAT and the Swiss Development Cooperation (SDC) was signed on 27 August to formally begin collaborative research activities in the West and Central African Millet Research Network (WCAMRN) or Reseau ouest et centre africain de recherche sur le mil (ROCAFREMI). This MOU allows transfer of funds from the SDC to ICRISAT to support member-NARSs to undertake approved research projects. In the long term, the network will facilitate productive linkages between ISC and the national programs, particularly in transfer and exchange of improved varieties and new production techniques.

MOU with Swiss Development Cooperation

This year, a PC-based data entry and editing system called the Research Project Management Information System (RPMIS) became operational at ICRISAT Center. It is used to coordinate ICRISAT's research at all locations. With the help of this information system, data on crops, disciplines, resources, collaborating institutions, trainees, geographical scope of research, target regions, and research activities can be easily retrieved.

Information System on Research Management Developed

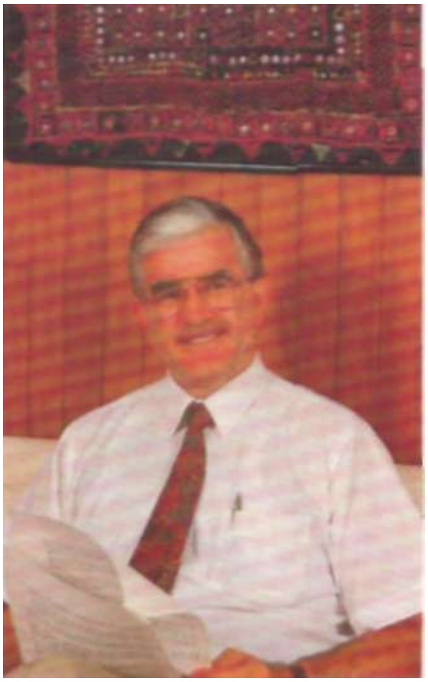
## Conclusion

As a new Director General, I feel privileged to be at the helm of such an outstanding and dedicated group of scientists and staff. It is my belief that the best is yet to come from ICRISAT in terms of scientific accomplishments and socioeconomic impacts. Twenty years of research on crops and environments neglected for so long has provided the necessary foundation on which to build future achievements.

An example is the identification, for the first time, of resistance to GRV, one of the most pervasive viruses affecting the groundnut crop in Africa. This was a dream when our Groundnut Program began in 1976. It took considerable cytogenetic and cell biology input to arrive at this position. ICRISAT was ahead of its time in recognizing the need to incorporate biotechnology to overcome this biotic constraint. The real dividends hopefully are about to be realized.

A second example is the release of the world's first pigeonpea hybrid. This has created considerable excitement in both the private and public seed sectors in India. The challenge is to capitalize on this unique achievement by enhancing resistance to pests in the new hybrids and to develop cytoplasmic male sterility to make hybrid seed production more cost-effective. We have opened exciting new opportunities; we require further research to effectively capitalize on them.

It is pleasing to note that the suite of downy mildew resistant improved pearl millet cultivars commencing with WC-C75, which ICRISAT developed with its ICAR collaborators, is currently generating new income streams for the poor in India far in excess of the current annual core budget of the whole Institute. This is but one of the many technology options the Center has been



instrumental in developing in the. past 20 years. We are confident with the initiation of more systematic economic assessments of the impact of our collaborative research with NARS commencing in 1992, we will be able to document even more convincing evidence of the wisdom of donor support for ICRISAT.

This Report illustrates clearly the increasingly strategic focus of ICRISAT's research portfolio. This has been a purposive strategy in recognition of the growing strength of many of our NARS partners, especially in Asia. Examples include the work on the role of central leaf whorl wetness in shoot fly susceptibility in sorghum, and the discovery of a new geminivirus of chickpea transmitted by leafhoppers. As we move away from the development of finished cultivars in countries such as India, the scope and value of strategic efforts such as these will increase. We recognize, as should donors, that as our strategic research agenda grows, it becomes more challenging to be able to assess the precise impact of ICRISAT's research. We are of the view that for this reason, and the increasingly collaborative nature of our relationships with NARS, assessments of socioeconomic impacts should not aim at separate attributions to NARS and ICRISAT, but rather at the joint impacts.

James G. Ryan

# Agroecological Zoning

An important prerequisite for planning the development of sustainable agriculture is an inventory of physical, biological, economic, and human resources. Status reports on these resources are also important. Since the distribution of natural resources varies across the globe, the inventory (termed agroecological zoning) usually involves measurement, assessment, classification, and mapping to delineate regions that have similar crops, soils, climate, and other resources.

*Digitization for agroecological zoning at ICRISAT Center.*

ICRISAT is using agroecological zones (AEZs) to define research domains to help set research priorities for its next Medium Term Plan. In India, a complete agroecological zoning at the subregional level has been carried out by the National Bureau of Soil Survey & Land Use Planning of the Indian Council of Agricultural Research (ICAR). This inventory is being used at ICRISAT Center. The environmental factors considered are: physiography, bioclimate, soil type, and the length of the growing season (LGS). This classification is rigorous and relevant to planning for sustainable land-use systems (Fig. 1).

## Climatic Zoning Schemes in the SAT

Most of the other simple climatic classification schemes are based on natural vegetation and mean annual rainfall. However, these schemes are inadequate for crop improvement research because:

- Mean annual rainfall alone cannot be considered as an adequate index of the probable LCS, since there are variations in potential evapotranspiration which influence crop yields.

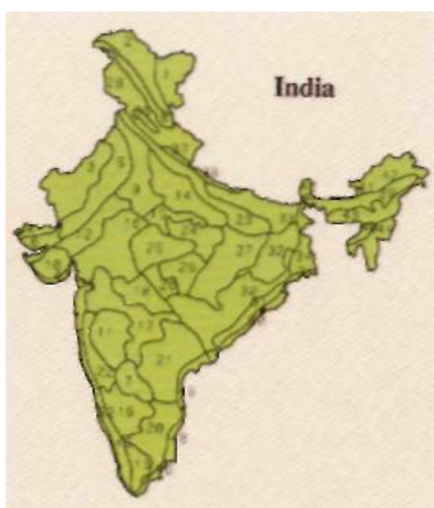



*Figure 1. Agroecological map of India with 52 subregions. Source: National Bureau of Soil Survey & Land Use Planning, ICAR. Nagpur, India (1991).*

- For annual cereals that are sown and harvested according to rainfall patterns in a given year, the most important constraint is the available LGS.
- Concepts and principles developed at a particular location in a climatic zone such *as* the Sahel cannot be extrapolated to the entire zone, since such soil characteristics as texture, slope, water-retention capacity, and inherent soil fertility all play very important roles in the performance of a crop variety. Distinct cropping patterns have evolved over the years under the influence of both climate and soils in the semi-arid tropics (SAT); and
- Streamlining research and development strategies to ensure cost effectiveness requires a characterization scheme that can be used to screen existing research locations and identify new sites where necessary. This requires adoption of more acceptable crop-dependant climatic criteria and suitable means of site characterization.

## Combining LGS and Soil Types in Western Africa

[redacted]n consideration of these factors, the approach of superimposing the LGS, calculated from rainfall and potential evapotranspiration, on the soils map was used. In the preparation of the soils map, only the dominant soil units from the larger Food and Agriculture Organization of the United Nations (FAO)/United Nations Educational, Scientific, and Cultural Organization (UNESCO) soils map of 1977 were used. This oversimplification, although at the risk of accuracy, eventually permits the identification of a reasonable and manageable number of climatic zones for application.

To maintain a degree of continuity with the simple climatic characterization, the rainfall limits used for that approach and the LGSs that correspond to these limits were examined. Using this procedure, a LGS of 60-100 days for the Southern Sahelian Zone, a LGS of 101-150 days for the Sudanian Zone, and a LGS of 151-210 days for the Northern Guinean Zone were obtained. The choice of these groups is also based on the present knowledge of the time taken by predominant pearl millet and sorghum cultivars to mature in western Africa.

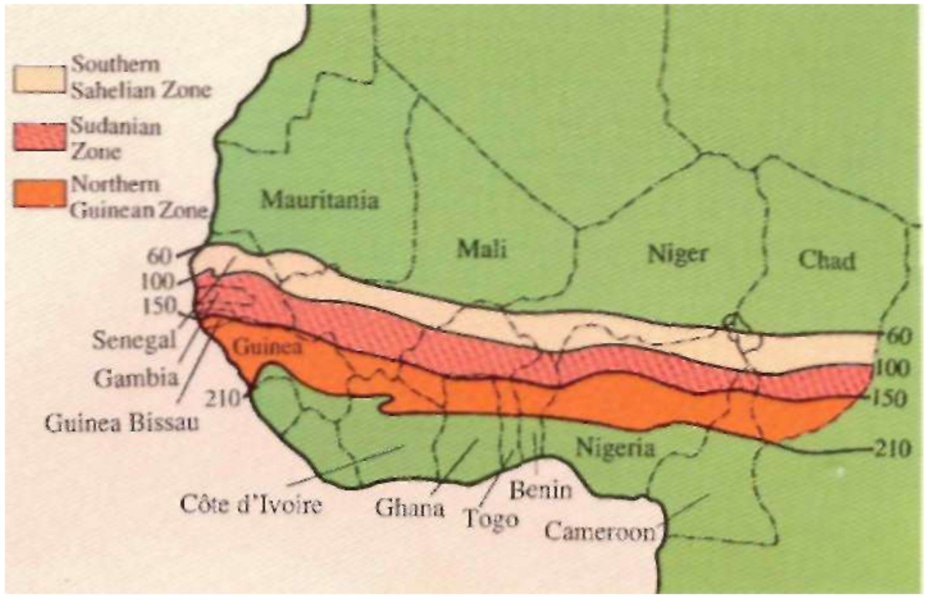



*Figure 2. The Southern Sahelian (LGS of 60-100 days), Sudanian (LGS of 101-150 days), and Northern Guinean <LGS of 151-210 days) Zones in western Africa.*

**Table 1. Agroecological zones: their approximate extent and priority ranking in western Africa.**

| Soil type | Climatic Zone | Length of growing season or LGS (days) | Percentage of total area | Priority ranking |
|---|---|---|---|---|
| Luvisols | Sudanian | 101–150 | 16.7 | 1 |
| Arenosols | Southern Sahelian | 60–100 | 15.6 | 2 |
| Luvisols | Northern Guinean | 151–210 | 10.8 | 3 |
| | Southern Sahelian | 60–100 | 5.4 | 4 |
| Acrisols | Northern Guinean | 151–210 | 5.5 | 5 |
| Nitosols | Northern Guinean | 151–210 | 2.6 | 6 |
| Vertisols | Sudanian | 101–150 | 2.8 | 7 |
| | Southern Sahelian | 60–100 | 2.1 | 8 |
| Regosols | Sudanian | 101–150 | 6.4 | 9 |
| | Southern Sahelian | 60–100 | 3.9 | 10 |
| Nitosols | Sudanian | 101–150 | 1.5 | 11 |
| Fluvisols | Northern Guinean | 151–210 | 1.1 | 12 |
| | Sudanian | 101–150 | 2.0 | 13 |
| | Southern Sahelian | 60–100 | 1.3 | 14 |
| Arenosols | Sudanian | 101–150 | 1.2 | 15 |
| Vertisols | Northern Guinean | 151–210 | 0.9 | 16 |
| Planosols | Southern Sahelian | 60–100 | 1.3 | 17 |

By superimposing the LGS isolines on the soils map, the major soil units in each of the three climatic zones (Fig. 2) were identified at the ICR1SAT Sahelian Center (ISC). In the Southern Sahelian Zone, Arenosols, Luvisols, Vertisols, and Regosols are the major soil units. In the Sudanian Zone, Luvisols are the major soil unit. The other important soils in this Zone are the Regosols, Vertisols, and Lithosols. In the Northern Guinean Zone, Luvisols, Lithosols, Nitosols, and Acrisols are the major soil units.

Given the human and financial limitations, all the soils obviously

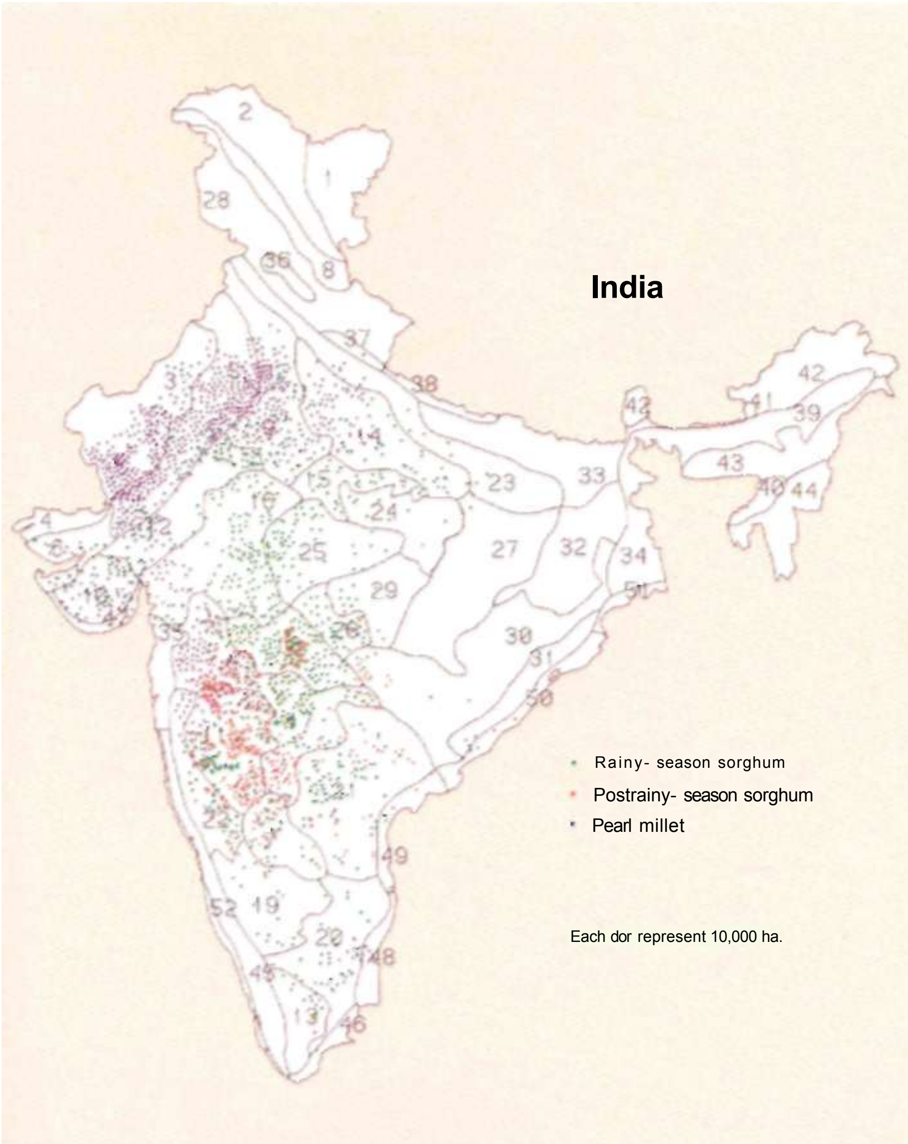



*Figure* 3. *Distribution of rainfed crops in the Indian agroecological zones (AEZs); pearl millet and sorghum in the rainy season, and sorghum in the postraiinj season. Sources: Agricultural Situation in India (1990), and National Bureau of Soil Survey & hand Use Planning, ICAR, Nagpur, India (1991).*

cannot be adequately covered by any regional research network while developing suitable technologies. However, from the extent of coverage of major soils in each climatic zone, the priority soil-climatic zones in western Africa were reduced to the 17 shown in Table 1.

## Agroecological Zoning for Pearl Millet and Sorghum in India

A Geographic Information System (GIS) approach using Arc-Info software was used to superimpose the agroecological map of India on the pearl millet distribution and the rainy- and postrainy-season sorghum distribution maps of India. The results of this study are shown in Figure 3.

Figure 3 shows that the pearl millet crop is mainly grown in the western plains of India on the desert-type sandy soils (agroecological subregions 3 and 5) and on shallow black soils (subregions 6,10, and 12) where the LGS is less than 90 days. Some pearl millet is grown on the Deccan Plateau (subregions 17,11, and 7) and in the eastern range of southern India (subregions 20,13, and 48). Here the soils are mainly red loamy (subregion 20), mixed red and black (subregion 13), or coastal alluvium (subregion 48). In all these areas, the LGS is <90 days, and crops fail every 2 or 3 years in 5. Some pearl millet is cultivated in the semi-arid zones comprising agroecological subregions 9, 14 (alluvial soils), and 21 on the Deccan Plateau in red and black soils. In these zones, the LGS varies between 90 and 120 days and risks to dependable pearl millet production are much lower (1 in every 5 years).

Figure 3 shows the distribution of rainy-season and postrainy-season sorghum in various Indian agroecological subregions. Rainy-season sorghum is widely grown in India across some 20 agroecological subregions (9 through 29). Much of the sorghum-growing areas fall within the semi-arid tropical Deccan Plateau where the LGS is between 120 and 150 days. Here the crop is grown on shallow mixed red and black soils with a water-retention capacity of less than 100 mm. Crop failure is recorded once every 5 years.

Postrainy-season sorghum is mainly grown in agroecological subregions 11, 17, and 18. In this Deccan Plateau area, the rainfall during the southwest monsoon is erratic; the soils are deep black with a water-retention capacity of 200-250 mm in the root profile. Sorghum is grown on conserved soil moisture. Therefore, in this area drought at the grain-formation stage of the crop can be devastating.

Pearl millet and sorghum, therefore, are grown in diverse AEZs in India. Multilocational testing of improved cultivars is essential to define specific adaptation zones. Testing new genotypes specifically suited to these well-defined AEZs instead of mass testing of genotypes in cooperation with the Indian national agricultural research system (NARS) is planned.

## Agroecology and Pigeonpea Distribution

As indicated earlier, LGS is one of the primary agroecological indices of crop adaptation in dryland farming areas. Examples of the suitability of land for pigeonpea cultivation in India and Africa are shown in Figures 4 and 5. Major pigeonpea-growing regions in India and Africa are located in red-soil regions that are dry (Tropustic Aridic), or of intermediate aridity (Tropustic Typic) soil moisture regimes (SMRs). Pigeonpea is also widespread in SMRs of varying temperatures that are wet (Tempustic Wet) and those that are monsoonal (Tempustic Typic). It is also grown to some extent in wet (Typic Udic) SMRs. Generally medium-duration cultivars that mature in 150-210 days are grown in dry (Ustic) SMRs of India. It was found that the red soil regions that are dry, or of intermediate aridity (Tropustic SMRs) stretch over a wide band extending from west to east in sub-Sahelian countries of Africa (Fig. 5) and some countries in central, eastern, and southern Africa. By analogy, all these areas would be potentially suitable for pigeonpea cultivation. Similarly, the crop could be grown in the wet (Typic Udic) SMRs of Congo, Zaire, and Uganda.

This AEZ information on pigeonpea has been used to establish our program in eastern and southern Africa that now has African Development Bank support. The information is being used by our pigeonpea researchers in Africa to locate collaborative research sites.

*(continued on p. 40)*

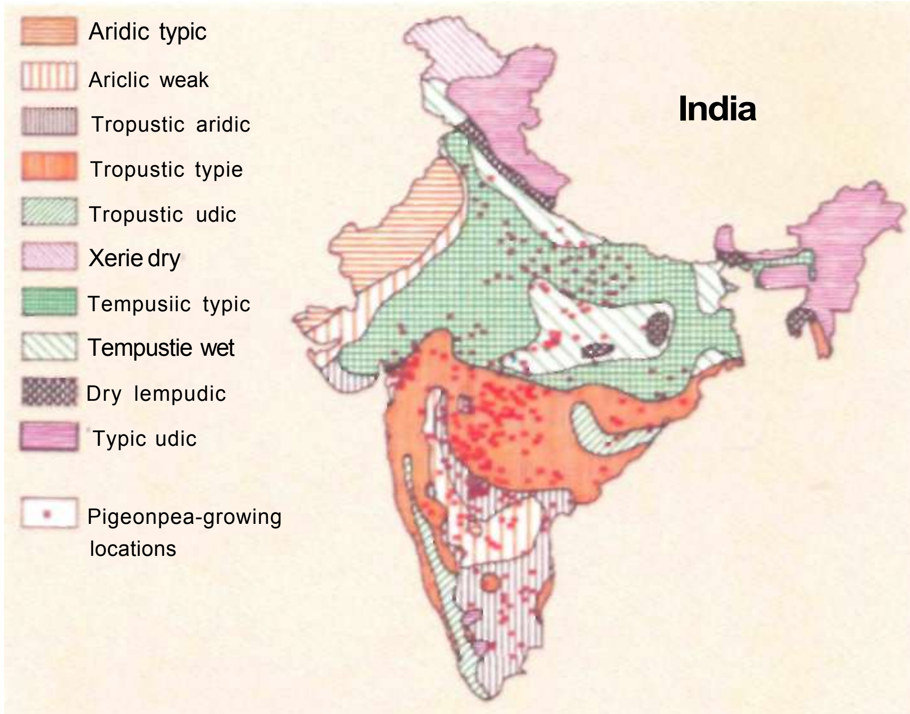



*Figure 4. Distribution of pigeonpea among soil moisture regimes of India. Sources: SMSS, A. Van Wambeke, Cornell University, USA (1985), and Agricultural Situation in India (1990).*

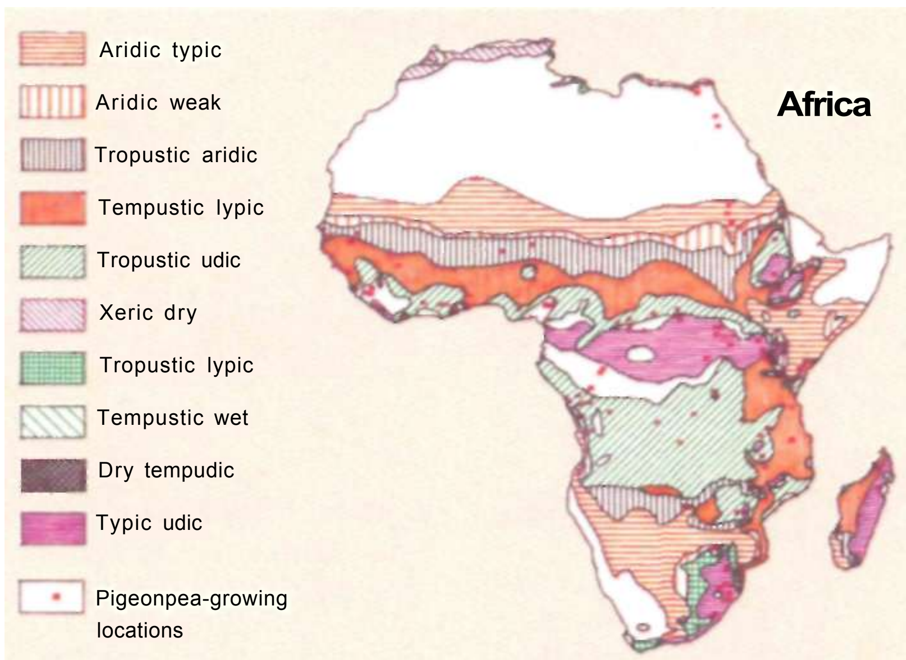



*Figure 5. Soil moisture regimes suitable for pigeonpea in Africa. Source: SMSS, A. Van Wambeke, Cornell University, USA (1985).*

# Use of Agroecological Zoning in Years of Good Rainfall in Niger and Senegal

*Farmers in certain parts of Niger and Senegal can now harvest two crops instead of one, when the rains begin a month ahead of their normal schedule, thanks to agroeeological zoning. Large deviations in the onset of the rainy season hi western Africa in the past two decades have resulted in considerable instability in crop yields. Therefore assuring some degree of yield stability for the farmer is a priority for both national governments and research institutions.*

*Normally, the average length of the growing season (LGS) can be easily computed from such data as the onset and end of rains. For example, in Niger the average LGS exceeds 100 days (Fig. 6). in the Gaya region of southern Niger the average LGS exceeds 120 days. From the analysis of long-term daily rainfall data for 300 locations in westem Africa, it is possible to predict and exploit the rainy season potential based on the relationship between the date of onset of rains and the LGS (ICRISAT Annual Report 1986, pp. 264-266). When the onset of rains is in May, a month earlier than normal, the LGS could exceed the average by 20-40 days because the end of the rains is more or less fixed. In field trials at ISC from 1986 to 1991, it was shown that in years when the onset of mins was early, the long groov-ing season could be exploited by growing a relay cowpea crop after the first crop of short-duration pearl millet. Cowpea is sown between the pear! millet rows 15-20 days before the pearl millet is harvested (ICRISAT West African Programs Annual Report 1988, pp. 61-64).*

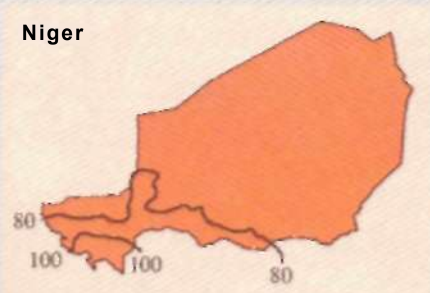



*Figure 6. Average LGS in Niger.*


*Figure 7. Probability (%) of LGS exceeding 130 days in years 'with an early onset of rains in Niger.*

*However, investigations on relay cropping were carried out only at ISC, It is important to delineate regions in Niger where this approach is applicable.It is possible to map such regions from the probabilities for LGS exceeding 130 days since the first crop of short-duration pearl millet requires 90-100 days to mature and the relay cowopea crop (a 50-60 day cultivar) is sown 15-20 days before the pearl millet harvest. A probability level of 50% was used to map the regions with relay cropping potential. Figure 7 shows the regions that offer a good prospect for relay cropping in years woth an early onset of rains. Such prospects are much higher in the Sudanian Zone than in the Southern Sahelian Zohe. National programs in western Africa are showing interest in the applications of this concept in their programs. In 1990, during a month-long stay at ISC, a scientist from the National Meteorological Services in Senegal analyzed rainfall data and prepared a report that clearly showed that consider-able potential for double cropping exists in Senegal (average LGS is shown in Figure 8). During normal years, relay cropping is a possibility only in regions where the LGS exceeds 130 days. However, in years when the rains begin about a month before the usual onset, the probabilities for a 130-day LGS exceed 50% over a much larger area (Fig. 9) and relay cropping could be recom-mended over this region. In some areas, the probabilities for a 150-day LGS exceed 50% and present additional possibilities for relay cropping of pearl millet and groundnut.*

*Therefore.the prospects for relay cropping are much higher in Senegal than hi Niger.*

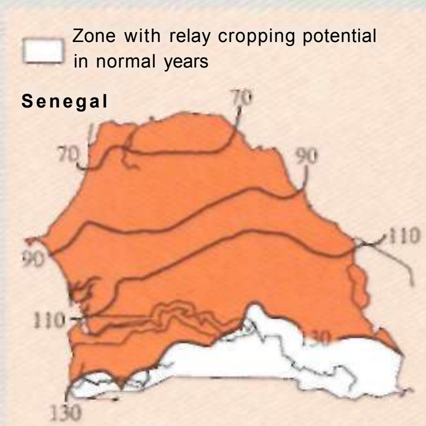



*Figure 8. Average LGS in Senegal.*

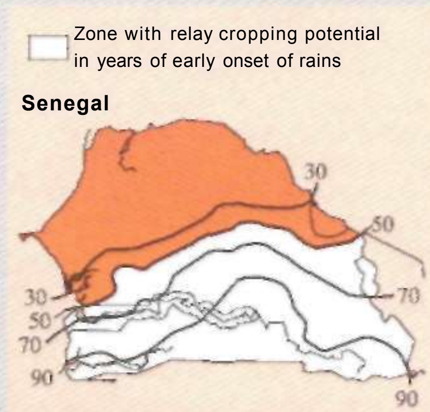



*Figure 9. Probability (%) of LGS exceeding 130 days in years with an early onset of rains in Senegal.*

(continued from p. 38)

## Use of Agroecological Zones in Networking

In view of the diverse conditions under which pearl millet is grown in the SAT, and of the local adaptation of particular varieties to specific regions, the need to evaluate pearl millet varieties that take varying length of time to mature at several suitable locations has long been recognized. The most significant effort in this area of multilocational evaluation of improved varieties of pearl millet to date in western Africa has been by the Institut du Sahel (INSAH) of the Comite permanent inter-Etats de lutte contre la secheresse dans le Sahel (CILSS). These trials, carried out over 4 years (1981-84), included 14 short-duration varieties (time to flowering 50-60 days), 5 medium-duration varieties (65-80 days), 5 long-duration varieties (>80 days), and a local control at 38 locations in seven countries. In India, this work has been carried out in cooperation with ICAR. In the African regional trials, varietal performance was evaluated using a climatic characterization of the 35 sites by placing them into one of the three rainfall classes: <400 mm, 400-800 mm, and >800 mm. This division, although useful, did not take into account differences in the dominant soil units among the locations and suffers from the same inadequacies described under the simple climatic zoning schemes-

Considering these factors, testing sites in different AEZs were selected. Mean annual rainfall at these testing sites ranges from 391 mm to 1523 mm. A summary of the AFZs for the 35 testing sites is given in Table 2.

From this summary it is apparent that Luvisols, the most important soil unit in western Africa, occur at 31% of all the sites. Arenosols are the major soil unit in the Southern Sahelian Zone covering 36% of the total sites in that Zone.

In terms of increased pearl millet production in western Africa, the Sudanian region offers considerable potential because of its good soils and long LGS. Hence, the potential of the existing soil units could also be extended, if possible, to include Vertisols that occur in both Cameroon and Chad within this Zone.

Pearl millet is not one of the major crops grown in the Northern Guinean Zone and hence the present coverage can be considered adequate. It may even be useful to consider reducing the number of testing sites in this region.

Superimposition of the range of traditional genotype and landrace characteristics, and hot spots for insect pests and diseases on the proposed AEZs might further help in understanding the complexity associated with pearl millet and sorghum adaptation in the SAT. In a major project on Adaptation Zones, currently underway at ICRISAT Center and ISC, a CIS study is being conducted to give further weightage to the agroecological zoning schemes described earlier.

**Table 2. Institut du Sahel testing sites in three agroecological zones in western Africa.**

| Major soil unit | Number of sites | | |
|---|---|---|---|
| | Southern Sahelian Zone | Sudanian Zone | Northern Guinean Zone |
| Arenosols | 8 | - | - |
| Luvisols | 4 | 6 | 1 |
| Regosols | 3 | - | - |
| Vertisols | 2 | - | - |
| Nitosols | 1 | 2 | 1 |
| Lithosols | 1 | 1 | 1 |
| Fluvisols | 2 | - | 1 |
| Cambisols | 1 | - | - |
| Total | 22 | 9 | 4 |

# Agroforestry and Perennial Systems

Perennial species such as trees, shrubs, and grasses have always played an important role in agriculture. Scientists are trying to comprehend the complex relationships between perennial species and food crops growing in close proximity. Some species aid crops by providing shelter, some trap wind-blown sand particles that can damage emerging crops, some provide shade in very hot climates, and some improve soil fertility and structure. Valuable insights have been gained into such relationships over several years of study on perennial systems in the semi-arid tropics (SAT).

*Harvesting pigeonpea fuelwood, ICRISAT Center, 1991.*



## Protecting Pearl Millet from Damaging Winds

In the Sudano-Sahelian region of western Africa, wind can lower the productivity of agricultural systems. A shift in the ecological balance in this region, through use of marginal lands, overgrazing, and removal of trees and shrubs, has created conditions that have accentuated wind erosion in the past two decades. Before the onset of rains in May, dust storms occur with violent winds in excess of 100 km/h causing serious erosion. Further, wind abrasion damages young pearl millet seedlings and sometimes the seedlings are buried under the sand. This often kills young seedlings and farmers are forced to resow their fields. At the ICRISAT Sahelian Center (ISC), it was found that scientific use of a perennial grass species *Andropogon gayamts* Kunth, a grass native to the Sahel, could benefit pearl millet farmers in the region. This species is usually not weeded out by farmers because it is used in construction and in making mats, and therefore has an economic value. The farmers also like to grow *Andropogon* because cultivation of the crop is not labor intensive.

A strategy to protect young pearl millet seedlings is to use vegetative barriers that serve as windbreaks, trapping

*Strips of* Andropogon gayanus *in a pearl millet field, ISC, Sadore, Niger, rainy season 1987.*

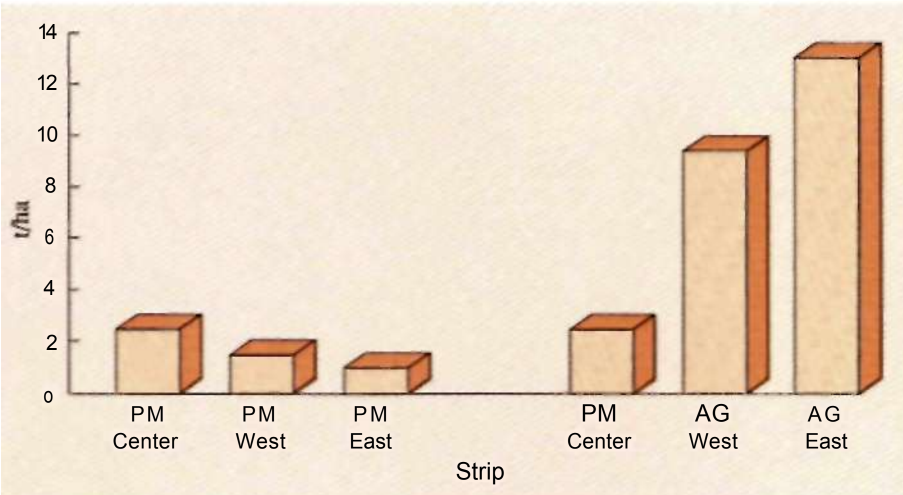



Figure 1. *Stover yields of pearl millet (PM) and* Andropogon gayanus *(AG), ISC, Sadore, Niger, rainy season 1989 (SEs for pearl millet = ±033; for* A. gayanus *= ±0.46).*

moving sand. From 1986-89 at ISC, pearl millet was sown between strips of *A. gayanus* 5 m apart and 100 m long. The field was oriented north-south and the *Andropogon* strips were laid perpendicular to the prevailing wind direction. Wind speed was monitored throughout the cropping season using anemometers placed 50 cm above ground level in the center of the plots. Pearl millet was sown between May and July for 4 consecutive years (1986-89), and harvested between mid-September and mid-October, depending on sowing dates.

In 1986, *Andropogon* was sown in pockets spaced 1 m apart. A year later the strips were effective wind barriers and helped reduce wind speed in the pearl millet plots until the end of July 1987, and also contributed significantly to the protection of pearl millet seedlings because no resowing was required in the protected plots.

In September 1989, a survey of soil elevation in *Andropogon* and cropped areas was made. There was a difference in elevation of 15 cm between these two areas. Taking a bulk density value of 1.5 g/cc for the sand, this indicates that over 3 years the *Andropogon* strips, trapped 112.5 t of sand, effectively protecting the seedlings at the beginning of the rainy season.

Pearl millet grain and stover yields from protected and nonprotected plots were not significantly different. Stover yields of millet and *Andropogon* for the east and west strips during the 1989 crapping season are presented in Figure 1. However, stover yields of *Andropogon* exceeded 9 t/ha and are of substantial economic value to farmers. The stover data for *Andropogon* are stover yields when cut at 40 cm above the ground, i.e., the portion the farmers actually use to make mats.

The value of *Andropogon* stover (in the Say market) in October 1989 was CFA 32/kg (CFA 270 = approximately U.S.$ 1) compared to CFA 16/kg for pearl millet stover and CFA 56/kg for pearl millet grain.

## Low Windbreaks Can Reduce Sand Movement

In a collaborative trial with the University of Hohenheim, Germany, the effect of low windbreaks on the amount of sand carried by early rainy-season windstorms was examined. It was found that the damaging sand particles are transported by wind close to the soil surface during the storms and that lateral movement of these particles can

**Table 1. Sand catch in a pearl millet field as a function of two distances from windbreak[1] and three heights above ground, ISC, Sadore, Niger, 12 Jun 1989.**

| Height above soil surface (cm) | Sand captured (g) | | | | |
|---|---|---|---|---|---|
| | 3 m from windbreak | | 10 m from windbreak | | |
| | *A. gnyanas* | *B. rufescens* | *A. gayanus* | *B. rufescens* | Control |
| 15 | 5.23 (0.79)2 | 6.15 (0.85) | 5.39 (0.80) | 7.11 (0.91) | 9.03 (1.00) |
| 50 | 0.73 (0.24) | 0.40 (0.14) | 0.55 (0.19) | 1.02 (0.30) | 0.89 (0.28) |
| 100 | 0.31 (0.12) | 0.08 (0.03) | 0.12 (0.05) | 0.13 (0.05) | 0.18 (0.09) |
| SE | | | (±0.038) | | |
| CV (%) | | | (11.7) | | |

1. Windbreak species were *Audropogon gayanus* and *B a u l t i n i a rufescens,*
2. Values derived from log transformation = log$_{10}$+1) of data set. SE and CV values are derived from transformed data and should be used only to compare numbers in parentheses.

be substantially reduced by low windbreaks.

Two species were examined: A *gayanus* and *Bauhinia rufesceits* Lam, a promising fodder shrub species. Windbreaks consisted of two staggered rows, 1.5 m apart, of l-year-old plants spaced 3 m apart within the rows. The young windbreaks were both porous and small; average height of the *Andropogon* was 65 cm, and of the *Bauhinia,* 155 m. Pearl millet cultivar CTVT was sown between the windbreaks.

During a dust storm on 12 Jun 1989, both windbreaks reduced sand carried at the soil surface (Table 1). However, it was found that, for both windbreaks and the control, the amount of captured sand decreased exponentially with height. This implies that most of the crop-damaging sand is lifted just above the soil during early-season storms, so that low, multi-purpose windbreaks can reduce the amount of wind-driven sand and, therefore, lessen damage to emerging crops.

## Studies on Low, Multipurpose Windbreaks in Farmers' Fields

Having established that low windbreaks composed of shrubs and perennial grasses can reduce the amount of sand carried by sandstorms at the onset of the rainy season, research at ISC focused on the use of low windbreaks.

In 1990, this research was expanded with an on-farm component. In collaboration with the Institut national de recherches agronomiques du Niger (INRAN), an on-farm research project began to investigate the feasibility of establishing low windbreaks in farmers' fields.

The windbreaks were planted on field boundaries and thus did not affect the area under cultivation. Competition with the existing crops, it was expected, should be limited. To give some incentive to the farmers, it was decided to use only such multipurpose species as the perennial grass A *gayamnus* and the woody species B. rufesceits, *Ziziphus mauritiana* Lam., and *Acacia Senegal* (L.) Willd.

The initial objective of the on-farm study was to investigate methods of establishing perennial vegetation on field boundaries and to quantify the effect of such management practices as protection against grazing and weeding, on the survival and growth of different species.

In two villages, Diakindi and Gueladio (south of Niamey in western Niger), a split-plot design was used with the species as the main plot factor, and weeding, boundary side, and

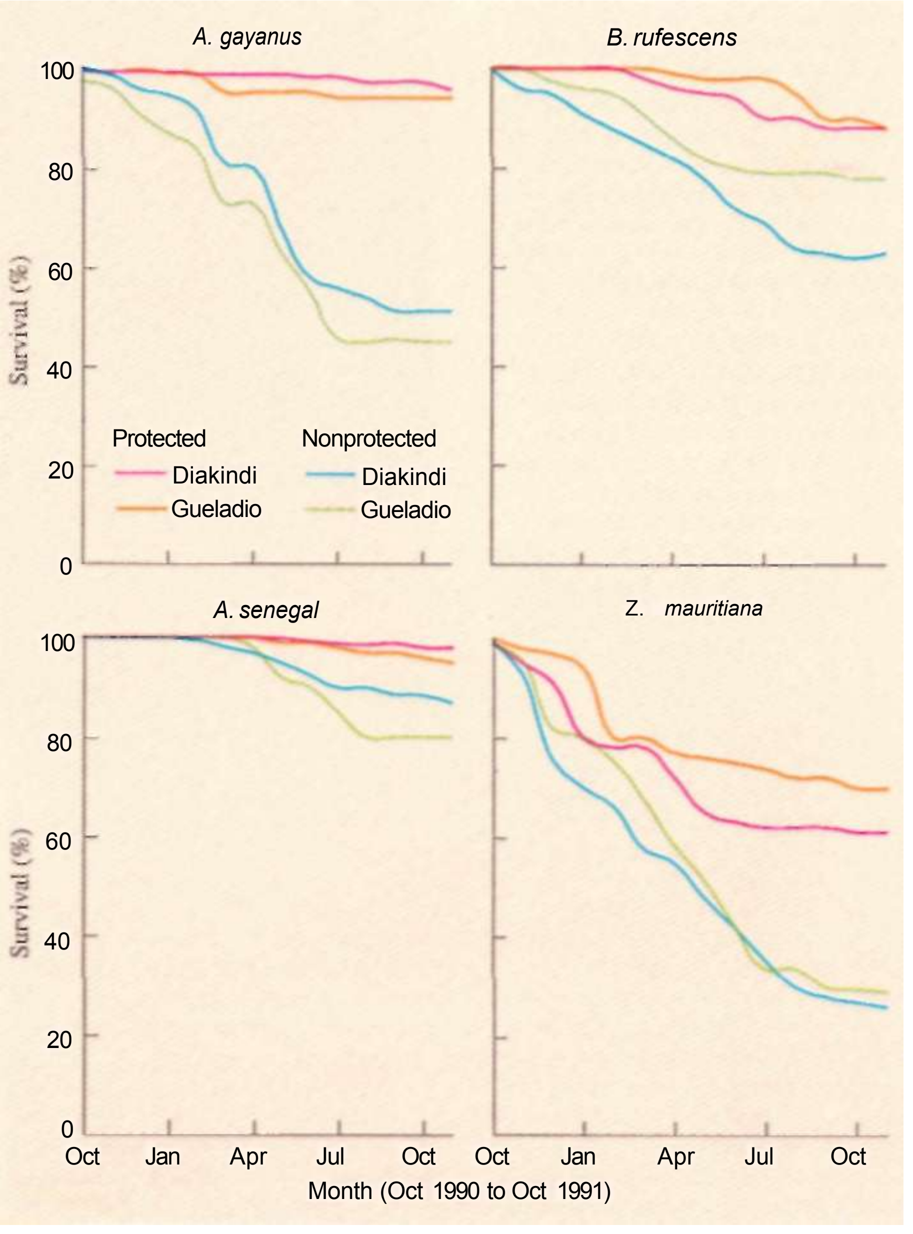



*Figure 2. Survival (%) of perennial windbreaks at monthly intervals in Diakindi and Gueladio villages. Niger/from October 1990 to October 1991.*

Agroforestry

protection as subplot factors. Each boundary was considered as a replicate. There were 24 boundaries in Diakindi and 21 in Gueladio.

In early August 1990, plants grown in ISC's nursery, were planted in the villages in two staggered rows on the field boundaries. The woody species were planted 3 m apart and the distance between the rows was 2 or 4 m, depending on the width of the boundaries. The grasses were planted 2 m apart and the distance between the rows was 2 or 3 m.

After 2 weeks, ISC staff weeded half of the transplanted seedlings and after 2-3 months, 10% of the plants were protected from browsing animals.

In the 2nd year, two more weedings were carried out in the plots, and dead plants replaced with ones of the same species.

From the beginning of the experiment until November 1991, survival counts of all plants were recorded every month, and growth measurements taken every 3 months on protected plants and controls.

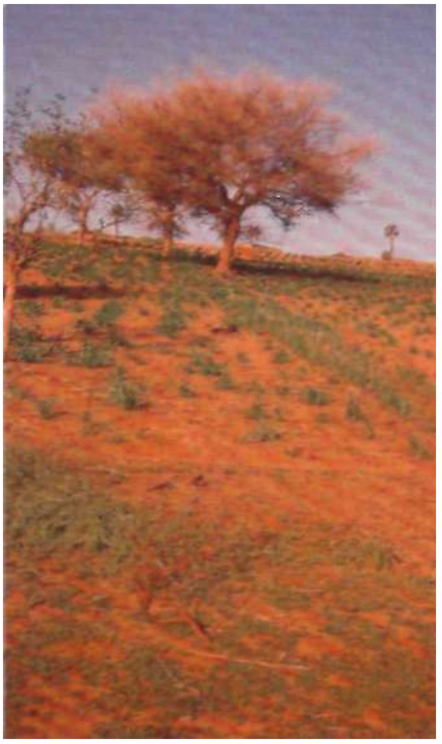
In both villages, all species except Z. *mauritiana* established well. Survival was above 92%, but for Z. *mauritiana* it fell to 62% in Diakindi and 75% in Gueladio.

The important factors in survival rates from October 1990 to October 1991 were species protection, and to a lesser extent, weeding.

Survival rates measured at monthly intervals (Fig. 2) show that the pattern is quite different between species. In Z. *mauritiana,* there was a very large difference between protected and nonprotected plants from the beginning (November 1990). In *A. gayanus* the positive effect of protection was not marked before February, and the same effect became apparent in April for *B. rufescens* and *A. Senegal.* Obviously the latter two are less browsed by animals than *A. gayanus.*

On combining survival data after 2 months (protected and nonprotected) and after 14 months for all four species, it was apparent that *A. Senegal* has the highest survival rate (92%), followed by *B. rufescens* (76%), *A. gayanus* (68%), and Z. *mauritiana* (33%).

Among the four species, Z. *mauritiana* has the lowest survival rate after establishment and is heavily attacked by browsing animals.



*Nonweeded strip between farmers' fields in Niger.*

The reactions of the farmers were quite similar in the two villages. According to them, fixing boundaries of new fields was advantageous because it avoids future conflicts. As for the choice of species, *A. gayanus* was the preferred one because of its economic value and its use in fixing field boundaries rather than for its relative performance in the experiment. It was followed by Z. *mauritiana, B. rufescens,* and *A. Senegal.* These preferences were based on the usefulness of the plants' products and not on their performances.

## Evaluating the Feed Value of Browse Species

Feed availability limits animal production in the Sahel. During the dry season, browses and bush-hays are major components of the basic livestock diet.

From 1990, a collaborative trial with the International Livestock Centre for Africa (ILCA) investigated the diet selection of sheep and goats grazing a 1.21-ha area of pearl millet stover in which strips of six browse species [B. *rufescens, Z. mauritiana, Acacia nilotica* (L.) Willd. ex Del., *A. Senegal, A. trachycarpa* Pritzel, *Faidherbia albida* (Del.) Chev.], and *Azadirachta indica* Juss. had been planted as windbreaks in 1988. Dry matter (DM) availability of browse leaves, pearl millet leaves and stalks, and weeds was determined at monthly intervals and bite counts on these DM components were recorded twice every week. Selective ratios (SRs) were calculated. A SR of +10 indicates maximum preference whereas -10 indicates total avoidance.

Of the total DM (4.61 t/ha) available at the onset of the grazing trial, 3.2% was browse leaves, 34.8% pearl millet leaves, 56.9% pearl millet stalks, and 5.1% weeds. Weeds in pearl millet fields were highly selected by sheep (SR = 8.2) and goats (SR = 6.8) during the 1st month of grazing. Sheep grazed pearl millet leaves (average SR = 3.1) and browsed the trees (average SR = 3.8) whereas goats predominantly browsed the trees (SR = —4.4 for grazing pearl millet leaves, and 9.1 for browsing trees). Browse species of periodic importance in sheep diet were *B. rufescens, A. nilotica,* and *A. Senegal.* Goats showed initial preference for *Z. mauritiana, A. Senegal,* and *A. nilotica* with B. *rufescens* highly selected during the latter part of the study. Longer-term monitoring is required to assess the impact of animals on fields with windbreaks.

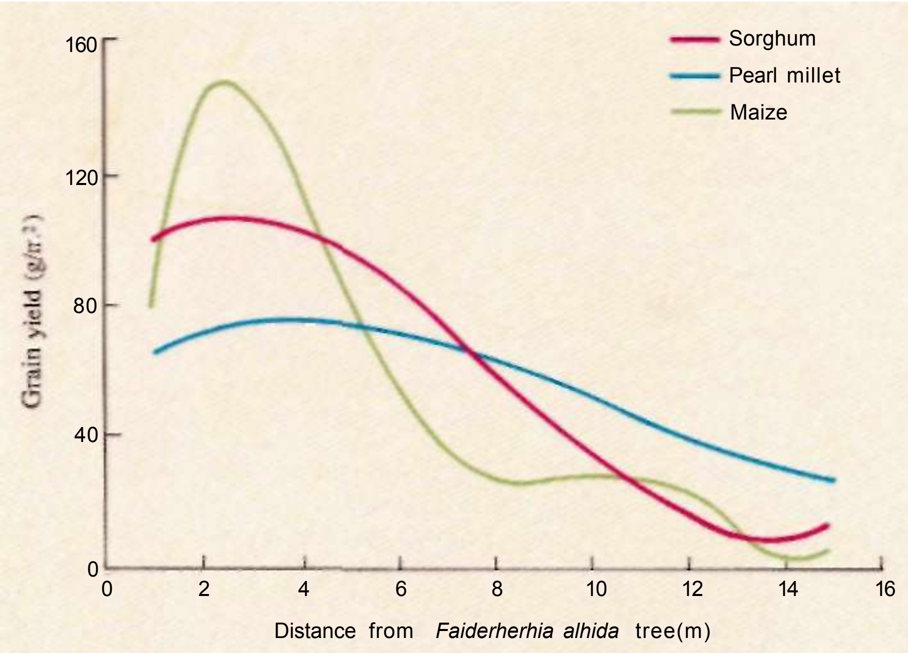



*Figure 3. Grain yield of sorghum, pearl millet, and maize as influenced by distance from* Faidherbia albida free*. *Means of eight replications. ISC. Sadore. Niger, rainy season 1991.*

*Faidherbin albida,* a tree of the dry regions of Africa, is well known to increase yields of pearl millet in its immediate vicinity- The exact extent of benefit from shade and that due to fertility is unclear. Research has shown that a wider range of crops can be cultivated than those that exist at present in the Sahel within the favorable micro-environment of *F. albida* trees. The experiment showed that close to *F. albida* trees, maize outyielded either sorghum or pearl millet, but the yields of this crop decreased dramatically with distance from the trees (Fig. 3). Away from the trees, pearl millet outyielded crops normally found in the cool and wet areas of the region. This research has wide implications for agriculture and horticulture in the region. A wider spectrum of crop species could be considered for cultivation in close proximity to F. *albida* trees and would be of benefit to farmers, who could accrue high economic returns from alternative crops.



## *Faidherbia albida:* Its Effect on Crops in the Sudano-Sahelian Region

Lack of crop diversity in the Sudano-Sahelian region is because of the inability of most crop species to tolerate the high temperatures that are common in the region. Maize, for example, is dominant in the cooler, wetter environments of the Guinean Zone, sorghum in the intermediate environments of the Sudanian Zone, and pearl millet in the hot, dry Sahelian Zone of western Africa.

Research over the past few years at ISC has shown that substantial gains in crop yields can be achieved by reducing radiation load and crop temperatures. Another constraint to crop growth is posed by low soil fertility. Pearl millet tolerates low fertility and low soil pH, while maize is highly responsive to fertility.

*Crops growing around a* Faidherbia albida *tree, Niger.*

## Perennial Pigeonpea: Advantages and Problems

[redacted]n much of the SAT, a considerable [redacted]roportion of the rainfall occurs outside the normal cropping season. Agroforestry species can be used to extend the period of production by better utilization of annual rainfall. The perennial nature of agroforestry species also encourages the formation of a deep and extensive root system. This root system can extract moisture and nutrients from subsoil layers largely unutilized by annual crops.

Apart from the better temporal use of resources, agroforestry systems can contribute to sustainability Improved soil fertility and structure can result from biological nitrogen fixation, litter fall, and root turnover. Litter fall of 1-2 t/ha has been measured during the first season of perennial pigeonpea agroforestry systems and 3-5 t/ha in the following year at ICRISAT Center. Reduced rates of runoff and soil erosion have also been measured. On an Alfisol at ICRISAT Center in 1987, agroforestry systems based on *Leucaena leucocephala* reduced runoff and erosion by >75% relative to annual crops (ICRISAT Annual Report 1988, pp. 185-186).

The intimate nature of the association between agroforestry species and annual crops often results in competition for limiting resources. This competition is often a major barrier to the adoption of this technology. Over several years, research at ICRISAT Center has aimed at understanding the extent and nature of this competition. This knowledge will help develop agroforestry systems that exploit the benefits of perenniality, yet minimize the negative effects of competition.

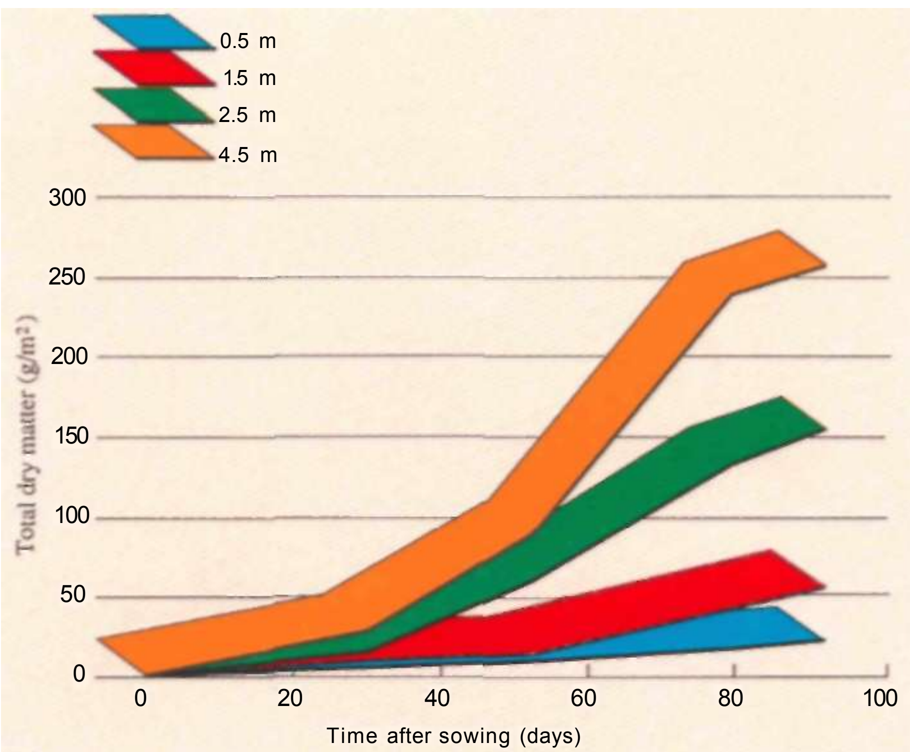



*Figure 4. Growth of chickpea in relation to the distance from the edge of an alley sown with 2-year-old perennial pigeonpea, ICRISAT Center, postrainy season 1989/90.*

In the SAT, where rainfall is erratic, crops often have to rely on stored soil water for extended periods. Dry matter production and yields of annual crops in the vicinity of the agroforestry species fall because of competition for water. Such competition is particularly evident during the postrainy season. Despite the deep root systems of agroforestry species, water is first extracted from surface soil layers at the expense of shaded annual crops. This is not surprising as a greater proportion of the root length of agroforestry tree species is found near the soil surface. In perennial pigeonpea, appreciable root length density occurred at distances greater than 1.5 m from the row. At ICRISAT Center with a perennial pigeonpea/chickpea intercrop (Fig. 4), or at the nearby Central Research Institute for Dryland Agriculture (CRIDA) with a *Leucaena/*castor (Ricinus *communis)* intercrop, yields of cash crops decreased in proportion to their proximity to the alley. Reduced cash returns from annual crops are unacceptable to many farmers despite the extra value of fodder and fuelwood harvested from agroforestry species.

Competition for light and water can occur even during the rainy season. Slow early growth of perennial pigeonpea in its 1st year resulted in some competition with an associated groundnut crop with yields of 1.22 t/ha compared with 1.92 t/ha in adjacent sole plots. In the 2nd year, the height advantage of pigeonpea and its extensive branching resulted in heavy shading of groundnut, low light interception (Fig. 5), and low yields. Groundnut yields in this system were reduced to 0.17 t/ha compared to 1.42 t/ha in sole plots.

There are many ways to overcome the problems of competition for light and water: use of erect agroforestry species, reduction in plant population, severe or repeated pruning, and use of agroforestry species that shed their leaves during the rainy season (e.g., *F. albida).* Alternatively, increased economic returns from agroforestry

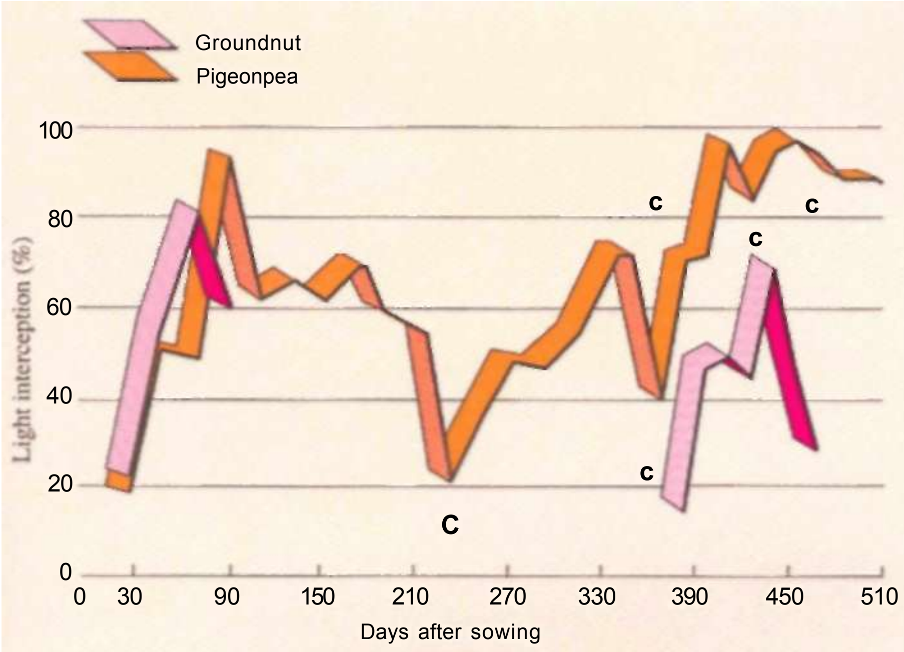



*Figure 5. Changes with time in the light interception of groundnut and perennial pigeonpea. In the 2nd year plants were pruned (C) to reduce competition, ICRISAT Center, 1990/91.*

species offset the losses farmers incur in annual crops arising from competition of the former.

ICRISAT has invested considerable resources on the study of agroforestry systems based on perennial pigeonpea (which needs to be resown every 3 or 4 years). These systems can be highly productive, give good returns for its seed, are easy to establish, and produce plenty of fodder during the dry season. A perennial pigeonpea/groundnut intercrop produced 28 t/ha of biomass over a 2-year period compared to the 10 t/ha produced by a sole groundnut crop (ICRISAT Resource Management Program Annual Report 1990, p. 28). Off-season production of fodder and fuelwood occurs when the demand is most acute, and labor is available to harvest these products.

While perennial pigeonpea has many clear advantages over other agroforestry species, it is not without its share of problems. Sterility mosaic and phytophthora blight diseases, and the insect pest *Helicoverpa arrnigera,* are major production constraints to short-duration pigeonpea that also affect perennial pigeonpea. Furthermore, increasing plant mortality has been observed after each successive harvest of fodder and fuelwood until, by the 3rd year, stands are devastated on both Vertisols and Alfisols. Further research on perennial pigeonpea agroforestry systems at ICRISAT Center has been suspended until the cause of this mortality is understood and lines with resistance found. However, much of the methodology and knowledge generated from these studies has direct relevance to the design and management of other agroforestry systems suitable for the SAT.

*Growth of castor between* Leucaena *alleys, CRIDA, Hyderabad, India, rainy season 1989.*

# Crop Utilization

ICRISAT's biochemists and breeders are constantly trying to improve the food and nutritional quality of the Institute's mandate crops for humans, livestock, and poultry. Recently they have been studying food processing and quality, and alternative end uses.

## Cereals

The ways in which sorghum and millets are processed into foods vary in different regions of the semi-arid tropics (SAT). There are many traditional foods including *to, uji, roti, injera, couscous,* and *fura.* To make these, consumers like to use soft cereal grains.


*White-grained sorghum can be used as a substitute for maize in poultry feed.*

Bread is a nontraditional food and its quality is crucially influenced by flour particle size. Soft cereal grains can be ground into finer flour than hard grains, another reason why consumers like them. In contrast, in western, southern, and eastern Africa, and some parts of India hard grains are preferred, because traditional food processing involves dehulling and hard grains are better suited than soft-grained genotypes to this process.

*Traditional pounding* (left) *of pearl millet heads and grain in Namibia; and queues* (middle) *at a modern null* (right) *that processes cereal grains in Zimbabwe.*

Dehulling is influenced by the size, shape, and hardness of the grain, and the thickness of the pericarp. Grain hardness is governed by its prolamine content. Traditional methods of dehulling are laborious and time-consuming but they can be made easier by selecting genotypes suitable for hand-pounding or by choosing appropriate mechanical dehullers. Studies revealed that it was possible to recover more dehulled grain from hard-grained genotypes and that such genotypes had higher prolamine contents than soft-grained genotypes, and that pearl millet genotypes with round grain could be dehulled faster than those with elongated grains.

### Traditional Foods

ICRISAT has initiated collaborative research projects to evaluate the quality of such traditional sorghum foods as *injera* and *nifro* with the Institute of Agricultural Research, Ethiopia; *ugali* with the University of Nairobi, Kenya; and *kisra* with the Food Research Centre, Sudan. The physico-chemical characteristics and dehulling quality of 16 sorghum cultivars commonly cultivated in all these countries were studied and food products made from them evaluated for their taste, smell, color, and general acceptance.

Among the 16 cultivars evaluated the ICRISAT-developed variety ICSV 112 (SPV 475/CSV 13) was found to produce the most suitable grain for the preparation of *injern, nifro, ugali,* and *kisra.*

### Malted Sorghum

Malting grains is a process that involves germination. Malted sorghum is used to produce several foods, including the opaque beers *chibuku, impeke,* and *pito,* and several weaning foods that are now commercially marketed in some African countries. Use of malted sorghum flour is becoming popular in Zambia and Tanzania, where it is promoted as 'power flour' in several regions.

Malting causes qualitative and quantitative changes in grain starch and protein. The amylase (diastase) enzyme produced during malting acts on starch to change the grains' physico-chemical properties. Malted sorghum markedly reduces the viscosity of food made from it. It helps to reduce the bulk density and to increase the nutrients and energy in food, particularly in weaning food.

### Composite Malts

The practice of using mixed malts of more than one cereal is common in traditional malting. This has not been fully exploited by industries in upgrading the malting quality of their products. At the SADCC/ICRISAT Sorghum and Millets Improvement Program (SM1P), the high diastatic activity of finger millet was used to boost the malting quality of commercial sorghum hybrid DC 75 after its own malting quality was reduced by storage in unfavorable postharvest conditions. The diastatic activity of DC 75 was boosted from 27.87 sorghum diastatic units (SDU) to 49.07 SDU (its normal range) using a 1:1 sorghum to finger millet composite malt. It was further raised to 55.67 SDU using a 1:3 composite malt.

In western Africa, sorghum is traditionally consumed as unfermented and fermented porridges and steam-cooked foods, e.g., *tuwo, ogi,* and *couscous.* A substantial portion of sorghum grain produced in the region is also used to prepare traditional beers, e.g., *dolo, burukutu, pito,* and *amgba,* by small-scale breweries. The recent ban on imports of cereal grains and malt into Nigeria has encouraged modern malting and brewing industries to use locally produced sorghum grain as the raw material for clear beer and malt extracts, increasing sevcralfold the

*Brown sorghum head and malt (before drying); drying sorghum malt in an African village; and malted finger millet ready for sale in Uganda.*

*Traditional cooking of cereals in southern Africa.*

demand for local sorghum malt. Sorghum malt extract is also used as a supplement in baby foods and confectionery items in Nigeria.

At present, malt is produced from the grain of an improved local sorghum variety, SK 5912, developed by the Institute for Agricultural Research, Samaru. However, there is a need for high-yielding sorghum cultivars with improved malting qualities. In this context, grain samples of elite sorghum genotypes recently bred at the West African Sorghum Improvement Program (WASIP), Nigeria, were supplied to five malting and brewing industries in Nigeria for preliminary analyses of their grain for various malting quality parameters.

ICRISAT also initiated work on screening for improved malting quality in collaboration with the Department of Food Technology, University of Ibadan, Nigeria, and the Scottish Crop Research Institute (SCRI), UK. Scientists at the University of Ibadan screened 18 elite sorghum genotypes for various malting quality parameters and found ICRISAT's early-maturing and advanced, pure-line variety ICSV 400 had a comparable malting quality to that of the control, SK 5912. Subsequent tests on grain samples of ICSV 400 grown in different seasons at various locations confirmed this observation. In contrast to SK 5912, ICSV 400 is potentially high yielding (>3.0 t/ha), photo-insensitive, short (<2 m), and has white, tannin-free grains. It is also acceptable for home consumption.

ICRISAT continues to refine laboratory test procedures to screen small grain samples for malting quality. A rapid test that could be used on small samples of grain (<25 g) would be a useful way to screen large numbers of breeders' lines to identify genotypes with superior malting quality and desirable agronomic characters. At the SCRI, 20-g grain samples from about 100 sorghum genotypes were studied for a range of malting quality characters. Significant variation among genotypes was observed for all the quality characters studied. Unlike barley, nonmalted sorghum grain milling energy was not related to malting quality parameters. However, malt milling energy was strongly related to diastatic power (-0.78, *P* >0.00!) and extract percentage (-0.75, *P* >0.001) indicating that it is possible to use milling energy estimations of small (5-g) sorghum samples as a rapid screening test. At SADCC/ICRISAT SMIP micromalting systems have been standardized for sorghum, pearl millet, and finger millet using 20-25 g grain samples. Their diastatic activity was also determined- Several improved and traditional sorghum genotypes of superior malting quality have been identified using these tests.

### Starch Production

Sorghum, pearl millet, and maize starches have several similar physico-chemical characteristics, such as viscosity and solubility. If starch from high-yielding sorghum varieties and hybrids is similar to maize starch, these genotypes could potentially be used to produce industrial starch. The relatively small grains of pearl millet, however, make it less suitable for starch production.

Starch recovery is frequently rendered difficult by the protein bound to starch granules. It was observed that treating sorghum grain with 1% papain solution increased starch recovery by 4% without affecting the starch.

### Animal Feeds

Most of the sorghum and pearl millet grain produced in the SAT is used for human consumption. The use of these grains as feed for animals and poultry is limited, but could be increased.

Maize grain is often used as poultry feed, but white-grained sorghum genotypes do not contain tannins and could therefore be used as a substitute for maize in poultry feed.

A preliminary feed study on layer and broiler poultry birds using white and yellow sorghum grain as a partial replacement for maize was conducted near Hyderabad, India. Maize and sorghum gave similar poultry yields (both eggs and broiler meat).

Feeding trials conducted in southem Africa in cooperation with the University of Zimbabwe on broiler chicks using medium [1.4% catechin equivalents (CE)] and low (<1% CE) tannin sorghums at 50%, 75%, and 100% replacement of maize showed that these sorghums performed as well as maize at all levels of substitution.

The quality of livestock meat depends on the nutritional quality of feed. Farmers in Asia, northern and southern Africa, and Latin America are interested in producing sorghum for use as feed to improve the meat quality of their livestock. This indicates an increasing demand for improved feed quality in the crop.

*Sorghum head infected by/ungi that cause grain mold.*

## Sorghum Grain Mold

The quality of sorghum grain is lowered and yield reduced by the fungi that cause grain mold. Studies at ICRISAT Center have revealed the association of both flavan-4-ols (polyphenols compounds found in sorghum grain) and grain hardness with resistance to grain mold.

Sorghum germplasm accessions were screened and those with resistance to grain mold identified. The concentration of flavan-4-ols in mold-resistant grains was at least twice as high as that in mold-susceptible grains at 30 days or more after flowering. The presence of flavan-4-ols was associated with sorghum grain that had a colored seed coat. Flavan-4-ols were not detected in white, mold-resistant lines. Mold resistance in white-grained sorghum genotypes without testae could be attributed to their having harder grains than mold-susceptible genotypes. These tests showed that both flavan-4-ols and grain hardness are associated with grain mold resistance.

Pathologists and breeders usually rely on visual examination to assess grain mold damage and to select genotypes that are least affected. However, such visual ratings can be erroneous. The concentration of ergosterol, a predominant sterol component in nearly all fungi, in mold-susceptible, mature sorghum grains was about 10 times higher than the ergosterol content in mold-resistant grains. The correlation coefficient between ergosterol and flavan-4-ols concentrations was significant and negative. Studies revealed that ergosterol concentration can be used to precisely assess the magnitude of mold damage in sorghum grains using a high-performance liquid chromatograph that can detect ergosterol concentration at microgram levels. This method could therefore become an important tool to supplement the selection criteria presently used by breeders and pathologists.

## Technology Evaluation

Comparative evaluation of two pilot-scale milling systems conducted in southern Africa, using an abrasive dehuller and a 2-roll roller mill indicated that sorghum grain conditioned to 16% moisture and directly roller-milled gave a higher milling yield than dehulled grain, and a flour of comparable whiteness and ash content to that from dehulled grain. The milling yield difference increased with decreasing grain hardness. A single-step roller milling technology has technological and economic advantages over abrasive dehulling.

The SADCC/ICRISAT SMIP has collaborated closely with Botswana's Ministry of Health to undertake a project in cooperation with a commercial milling company, Foods Botswana, to create a weaning food from a mixture of sorghum and soybean flours (ICRISAT Report 1990, p. 59). This collaboration has developed to the contracting phase, and the Botswana Government has put out tenders for weaning food production.

Other collaborative interactions between SMIP and industries elsewhere initiated in the 1989/90 season, resulted in cost-sharing cooperative activities in 1991. As research moved into evaluation of end-user systems, interactive models linking producer to processor were developed and involved experimental contract farmers (producer) and industrial end-users. The following are examples of these interactions:

- *The Multidisciplinary Composite Flour Project* entered the first phase of implementation. On-farm production of two white sorghums of selected milling quality, SDL 81046 (from SADCC/ICRISAT SMIP) and SV 1 (control), was contracted to a medium-scale farmer in the 1991/92 season, for scaied-up milling and baking trials.

- *The Sweet Sorghum Quality Evaluation* (SSQE) entered the first stage of adoption with seed multiplication of four selected sweet sorghum entries from the SSQE trials over 3 years (1988-90). Seeds of three entries were made available to the sugar/ethanol industry in Zimbabwe for seed increase and stalk production in the 1991/92 season. Processing quality and ethanol yield of the selections were evaluated at SADCC/ICRISAT SMIP and found to be acceptable.
- The quality of pasta made from the flour of two white sorghums, WSV 3S7 (released in Zambia) and SV 2 (released in Zimbabwe), was compared. Pasta made from flour containing 30% sorghum of both genotypes was rated above the baseline of acceptability but was significantly different (P<0.01) from the control 100% wheat pasta in color and general acceptability; pasta made from SV 2 grain rated significantly (P<.05) higher than that of WSV 387 grain. Product optimization is up to commercial standards, and seed supply and grain production are to be facilitated by SADCC/ICRISAT SMIP.



## Legumes

## Chickpea and Pigeonpea

Chickpea and pigeonpea provide valuable sources of protein for people in developing countries, particularly among those low-income groups who depend on vegetarian diets for economic and social reasons. These legumes also supply calories, vitamins, and minerals. Seeds of both chickpea and pigeonpea are usually eaten after dehulling as *dhal* (decorticated, split dried seeds). In some African, Asian, and Caribbean countries, they are eaten as boiled, whole seeds, and the green immature seeds are used as a vegetable.

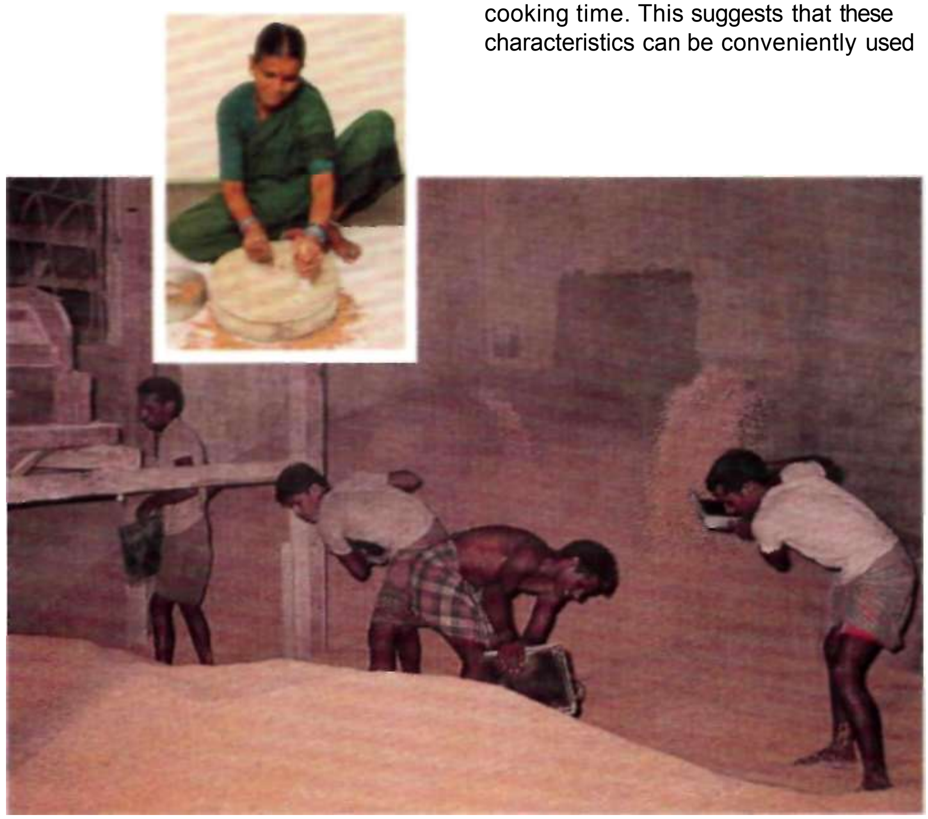
### Dehulling Characteristics

Pulses are traditionally dehulled either commercially by large-scale processing in mechanically operated *dhal* mills, or by domestic small-scale methods that are common in villages. Limited surveys by ICRISAT have indicated that the recovery *of dhal* varies with the processing technique used. During the surveys, it was observed that in small-scale dehulling, the mean chickpea *dhal* yield was 70.8%, whereas in large-scale dehulling, it was 805%. In general, millers prefer desi chickpea cultivars with light-brown testae and medium-sized seed. In small-scale dehulling, the mean pigeonpea *dhal* yield was 62%, whereas in large-scale dehulling it was 70.6%. According to *dhal* millers, hard, round, and medium-sized pigeonpea seeds yield more *dhal* than soft seeds of other shapes and sizes.

The dehulling process results in considerable losses of protein, calcium, and iron; important dietary nutrients contained in both pulses. Analyses of many chickpea and pigeonpea genotypes revealed differences in their dehulling quality characteristics. Genotypes that yield more *dhal* when they are dehulled than existing cultivars need to be identified and developed.

### Cooking Quality and Consumer Preference

The influence of physico-chemical factors on the time taken to cook pigeonpea and chickpea seed was evaluated at ICRISAT Center. Among these factors, water absorption, solids dispersion, texture, and phytic acid are significantly correlated with the time taken to cook pigeonpea. Calcium, magnesium, and pectin contents of pigeonpea are also correlated with its cooking time. This suggests that these characteristics can be conveniently used



*Large-scale processing in a* dhal *mill in India.* (Inset) *Grinding pulses in a traditional hand mill.*

*Determining the texture of chickpea with an Instron Food Testing Machine.*

as objective tests to determine cooking time in pigeonpea genotypes. In chickpea, only water absorption, solids dispersion, texture, and magnesium content appeared to influence cooking time.

A procedure that involves an Instron Food Testing Machine (IFTM) was standardized at ICRISAT Center to determine the texture (a direct index of hardness) of chickpea and pigeonpea *dlials.* This objective method could be used in future to predict the time taken to cook both chickpea and pigeonpea *dlials.*

Pectinase enzyme and sodium bicarbonate treatments could potentially be used to develop *dhal* that cooks rapidly Rapid cooking *dhal* could reduce domestic fuel consumption.

In some African countries, pigeonpea is consumed as whole seed cooked to a soft consistency, but pigeonpea is often less popular than cowpea because it takes much longer to cook. The cooking times of pigeonpea and cowpea, with and without 16-h presoaking treatments using either water or a sodium bicarbonate solution (1% w/v), were compared. Although the nonsoaked pigeonpea took much longer to cook than the cowpea, after presoaking pigeonpea cooked faster than cowpea.

Results of experiments on pigeonpea indicated that cooking time varied with the season in which the crop was grown and that genotypes grown in the postrainy season took longer to cook than those grown in the rainy season.

Other studies indicated that kabuli chickpeas had advantages in cooking time, color, taste, and smell over desi chickpeas.

### Nutritional Attributes of Newly Developed Genotypes

Nutritional aspects of newly developed genotypes of chickpea and pigeonpea have been continuously monitored and compared with those of popular cultivars. In general, the levels of various chemical constituents and protein-quality characteristics are similar, but two newly developed ICRISAT chickpea genotypes, ICCV 1 and ICCC 37, were found to contain considerably higher levels of calcium and iron, than those of the commonly grown cultivars, Annigeri and K 850. Calcium and iron are important nutrients that are usually deficient in the diets of low-income populations.

### Antinutritional Factors

Scientists at ICRISAT Center studied factors in chickpea and pigeonpea that hinder the digestibility of their proteins and carbohydrates. Examples of such factors are trypsin, chymotrypsin, polyphenolic compounds, amylase inhibitors and phytic acid.

Although chickpea and pigeonpea contain much less trypsin and chymotrypsin than soybeans, some of

*Indian women fanners examining vegetable pigeonpea pods.*

the wild relatives of pigeonpea were found to contain higher concentrations of the protease inhibitors that influence protein digestibility in legumes than cultivated species. The highest trypsin and chymotrypsin enzyme-inhibiting activities were observed in *Rhynchosia rothi* and this species also had the lowest in vitro protein digestibility of the materials tested. The presence of some of these inhibitors may have a role to play in insect- or disease-resistance characteristics.

The polyphenolic compound contents of seeds of desi chickpea were found to be more than double those of kabuli chickpeas and these differences were not apparent in *dhal* samples made from the two types. This indicated that the distribution of these compounds is mainly in the seed coat. Since these are removed during dehulling, polyphenolic compounds showed a highly significant and negative correlation with in vitro protein digestibility.

A statistically significant negative correlation was observed between amylase inhibitor activity and digestibility, indicating that the digestibility of starch is adversely affected by the level of amylase inhibitor.

Both chickpea and pigeonpea contain raffinose and stachyose, which are flatulence-causing sugars.

Phytic acid interferes in mineral utilization. Chickpea contains more phytic acid than pigeonpea. Cooking considerably reduced the levels of phytic acid in pigeonpea but not those in chickpea. Germination reduces the levels of phytic acid in both chickpea and pigeonpea.

These results will help ICRISAT and NARS breeders to identify genotypes of the two legumes with lower levels of such antinutritional factors with the help of biochemists. If techniques are developed to remove or reduce their levels, the consumer acceptance of these legumes could increase.

## Groundnut

### Oil Content and Quality

Groundnut is the major source of edible oil in several countries of the SAT. There is considerable variation in the oil contents of groundnut germplasm accessions. About 9000 groundnut germplasm accessions and wild *Arachis* species were analyzed for their oil, protein, and moisture contents. On the basis of these analyses, several germplasm accessions were selected for further investigation.

Oil quality is determined by the composition of the fatty acids it contains. The fatty add composition of over 3000 groundnut samples grown in different environments was determined, in an attempt to understand the variability in two important fatty acids: oleic acid (O) and linoleic add (L).

The oleic acid to linoleic acid ratio determines the shelf-life of the product; the higher the ratio, the longer the product is stable. An oleic acid to linoleic acid ratio of at least 1.6:1 has been recommended by groundnut commercial buyers, because this ratio ensures product stability. Groundnut products with a high P/S ratio (the ratio of polyunsaturated fatty adds to saturated fatty acids) are nutritionally superior to those with a low P/S ratio. A negative relationship between O/L and P/S ratios poses a challenge to groundnut breeders wishing to develop nutritionally superior cultivars with increased product stability. At ICRISAT Center, 10 confectionery varieties with low oil (45-46%) but relatively high protein (25-28%) contents and with improved balance in O/L and P/S ratios have been seleded. Efforts will be made to further improve this critical balance of O/L and P/S ratios during the development of confectionery varieties.

### Cooking Quality

In several parts of Asia and Africa, groundnuts are boiled in their shells in salt water and eaten when the seeds are cooked. Valencia types with a high proportion of three- and four-seeded pods, large tan/rose seeds low in oil, and with a sweet taste are preferred by Southeast Asians. Forty-four germplasm lines with a high proportion of four- and three-seeded pods were identified. These lines are currently in yield trials. Some of them, though low in 100-seed mass, had low oil and relatively high protein contents, and a sweet taste. But generally, their O/L ratio was low (0.8-0.9:1) and P/S ratio high (1.6-1.9:1). Methods were standardized to estimate the time needed to cook freshly harvested and cured groundnut seeds, and the time needed to cook unshelled pods.

### Biological Evaluation

Using rat bioassay, groundnut genotypes that were grown in rainy and postrainy seasons were biologically evaluated.

It had already been established that genotypes grown in the postrainy season have a higher protein content and better amino add composition than the same genotypes grown in the rainy season. On evaluating some groundnut genotypes, the digestibility of protein (proportion of absorbed food nitrogen) was found to be significantly higher in postrainy-season genotypes than in rainy-season genotypes. However, the biological value (the proportion of absorbed nitrogen retained in the body for maintenance and growth), and net-protein utilization (the proportion of retained nitrogen intake) were significantly higher in the rainy-season genotypes. The digestibility of blanched groundnuts, i.e., those with their seed coats removed, was also significantly higher than that of whole seeds.

# Genetic Resources and Germplasm Enhancement

*Evaluation of Sudanese sorghum germplasm in Sudan.*

Nature has provided humankind with a treasure of plant genetic resources. In its efforts to conserve this precious commodity, ICRISAT continues to collect germplasm jointly with national agricultural research systems. The Institute also catalogs and conserves the largest global germplasm collection of its mandate crops and their wild relatives. This collection at ICRISAT Center, freely available for use in crop improvement research throughout the world, is an invaluable resource for long-term and strategic agricultural research. Some of these accessions have certain desirable traits that are used in scientific efforts to breed genotypes superior to existing ones. The potential of a large part of the collection, however, is yet to be fully realized. The accessions could contain desirable genes for future crop improvement.

Germplasm enhancement increases the expression of a desired trait in a plant. This involves a series of breeding procedures to combine desirable genes. The incorporation of resistance to a disease controlled by different genes in different parents into a single genotype is one such example.

## Sorghum

### Germplasm Collection and Evaluation

ICRISAT received 218 new accessions from Pakistan, Togo, Honduras, and India during the year, raising the total collection in the gene bank to 33108 accessions.

During the rainy and postrainy seasons, in collaboration with the National Bureau of Plant Genetic Resources (NBPGR), 196 accessions were selected and evaluated for grain yield potential and 200 for forage characteristics. Sorghum breeders from various institutions of ICAR, agricultural universities, and private seed companies in India selected material for use in their breeding programs. A joint ICRISAT/ICAR catalog of forage sorghum germplasm was published during the year.

In collaboration with the International Sorghum/Millet, Collaborative Research Support Program (INTSORMIL) and the Sudan Regional Program, 2 340 accessions of Sudanese origin were characterized at Wad Medani, Sudan. The release in Sudan of a Strign-resistant sorghum

Sorghum austrialiense, *a recently identified wild sorghum with a high level of resistance to shoot fly.*

germplasm line, IS 9830, as Mugawim Buda 2, was the result of such evaluation of germplasm lines.

Four germplasm lines, IS 2301, IS 2391, IS 8283, and IS 18688, were found to be resistant to leaf diseases and ergot (*Claviceps sorghi*) across locations in Zambia and Zimbabwe where these diseases incur losses. Eight zera-zera lines, IS 30469C-144, IS 30469C-630D, IS 30469C-630T, IS 30469C-724, IS 30469C-1157, IS 30469C-1161, IS 30469C-1518T, and IS 30469C-1713, were found to be resistant to four diseases: leaf blight (*Exserohilum turcicum*), anthracnose *(Colletotrichum graminicola)*, zonate leaf spot (*Gloeocercospora sorghi*), and ergot.

At ICRISAT Center, after screening 349 progenies of crosses involving *Sorghum dimidiatum* (Stapf) Garber, a wild parasorghum, and cultivated sorghum for resistance to shoot fly (*Atherigona soccata*), 257 single plants with 'zero' egg-laying trait and 'zero' dead hearts were selected. This material will be used in attempts to develop improved genotypes with resistance to shoot fly.

*Breeders from Indian NARS selecting promising sorghum lines at ICRISAT Center.*

*Sorghum germplasm collection in Uzbekistan, Commonwealth of Independent States.*

### Germplasm Enhancement

In western Africa, selection and backcrossing continued in efforts to develop a caudatum and guineense composite using entries with the genetic male-sterile $ms_3$ line and other selected parents, such as those with grain mold resistance. Thirty-three $F_2$ populations derived from crosses involving resistant sources for grain mold, midge (*Contarinia sorghkola*), and head bugs (*Eurystylus* sp) were grown and 40 plants were selected, 6 of which were from crosses involving Malisor 84-7, a source of head bug resistance. Over 90 single plants were selected from 160 $F_4$-$F_7$ progenies.

## Pearl Millet

### Germplasm Collection and Evaluation

With the addition of 93 accessions from India, 45 from Mali, and 935 from Namibia, the number of accessions conserved at ICRISAT Center rose to 22059 from 44 countries. Twenty-one wild *Petmisetum* sp collected from the Garhwal and Kumaon hills, India, appear to be good sources of cold-tolerance traits.

During the 1991 rainy season, 1747 accessions were evaluated and characterized. Some 910 photoperiod-sensitive lines produced larger spikes when grown from July to December and their appearance at different locations was similar to that found in farmers' fields at the time of collection.

Accessions that produce large spikes and/or large grain were identified for conversion. In collaboration with NBPGR and the All India Coordinated Pearl Millet Improvement Project (AICPMIP), ICR1SAT evaluated 200 accessions for grain yield and 200 for fodder yield at various locations in India.

The new collection from Namibia was multiplied, evaluated, and crossed by the Southern African Development Coordination Conference (SADCC)/ ICRISAT Sorghum and Millets Improvement Program (SMIP) in Zimbabwe. Seed from the multiplication evaluations and crosses were sown in northern Namibia to expand the pearl millet improvement program jointly initiated there by the Namibian Ministry of Agriculture, Water, and Rural Development and ICRISAT.

*Pennisetum foenneranum* Leeke, collected in Namibia, is a new addition to ICRISAT's gene bank. Besides random samples for conservation, 47 deliberately picked, agronomically elite, geographically diverse samples of the species were collected for immediate use in pearl millet improvement in Namibia.

### Wild Millet

Crosses between the wild millets and a range of cultivated millets are used in the diversification of sterile cytoplasms in the development of seed parents (male-steriles) and maintainers. Geneticists of the Institut francais de recherche scientifique pour le developpement en cooperation (ORSTOM) working at the ICRISAT Sahelian Center (ISC) have made extensive collections of the wild millet [*Petmisetwn glaucum* (L.) R. Br. subsp. *monodii* (syn. *P. violaceum* Lam. L. Rich)] from several western African countries and from Sudan. These accessions and cultivated millet *[P. glaucum* (L.) R. Br. subsp. *glaucum]* were used to study the geographic distribution of polymorphism in eight enzymes.

*A wild millet accession from Mali, part of a large collection assembled by ORSTOM, growing at ISC, Sadore, Niger, rainy season 1989.*

Results indicated that wild millet has a large genetic diversity structured into five groups corresponding to geographical areas. Domestication appears to have occurred as a unique event in the western region (Mauritania, Senegal, or western Mali) where the greatest similarity is now observed between wild and cultivated millets.

Over the last 4 years, ICRISAT in collaboration with ORSTOM, found all the wild millets tested to be susceptible to *downy* mildew *(Sclerospora graminicola)* with the exception of two from Senegal that remained disease free. None of the entries were free from smut (*Tolyposporium penicillariae*) and the lowest ratings were between 7.5% and 8.8% on two accessions from Mauritania and one from Niger. However, wild accessions were found to be less susceptible to ergot (*Claviceps fusiformis*) than the local control.

## Germplasm Enhancement

Several germplasm accessions were directly used to develop improved pearl millet varieties at the former ICRISAT-Institut d'etudes et de recherches agricoles (INERA) cooperative program in Burkina Faso and at ISC. In Burkina Faso, varieties IKMP 1, IKMP 2, IKMP 3, and IKMP 5, are now recommended for on-farm testing/cultivation by farmers in specific agroecological zones and sowing conditions. ICRISAT has provided breeders' and foundation seed of these varieties to Burkina Faso. This year varieties IKMP 2, IKMP 3, and ICMV 88102 were recommended for inclusion on the official list of promising varieties in Mali by the Commission technique des productions vivrieres et oleagineuses of the Institut d'economie rurale (IER). Seed of these varieties will now be multiplied for on-farm tests by extension agencies in Mali. Variety ICMV-IS 88102 gave a superior and stable performance in the Southern Sudanian and Northern Guinean Zones of Mali. As observed in other pearl millet improvement programs in the region, the most useful germplasm with desirable variability is Iniadi, a prominent, productive, bold-seeded, and early-maturing landrace found in Benin, Burkina Faso, Ghana, and Togo. In 1989, an Iniadi germplasm collection mission was undertaken in collaboration with the Direction de la recherche agronomique, Direction generate du developpement rural of the Ministere du developpement rural, Togo. The team collected 480 samples in northern Togo. An early, bold-seeded variety, GB 8735, developed *from* crosses between Iniadi and Souna (an early pearl millet from Mali) was supplied to the Direction de la recherche agronomique, Togo, where 2 t seed were multiplied and distributed to farmers for large-scale evaluations.

Enhancement activities in southern Africa include the development of superior varieties and parents from composite populations. Seven

*Heads of Iniadi, a productive, bold-seeded, and early-maturing pearl millet landrace from Togo. Iniadi has been found to be the most useful source of variability in several breeding programs.*

composite populations have gone through two cycles of recurrent selection, A composite bulk trial conducted during the 1989/90 and 1990/91 seasons at 7-11 SADCC locations had gains in grain yield ranging from 2.0% to 5.3% per annum. In both seasons, the composite bulks generally gave higher yields than (he controls (ICMV 82132 and SDMV 8900' indicating the possibilities of developing new and superior varieties from them.

## Minor Millets

### Germplasm Collection and Evaluation

From the hilly areas of Orissa, India, 62 new accessions of minor millets were collected, raising the total gene-bank holdings to 7144. Of these

*Heads of high-yielding finger millets from Kenya identified during germplasm evaluation in Zimbabwe.*

holdings, 244 minor millet samples from India, Japan, the Maldives, Pakistan, Taiwan, and Zimbabwe were rejuvenated and conserved in medium-term cold storage. One-hundred and thirty new finger millet accessions were grown for quarantine inspection, seed multiplication, and release.

At SADCC/ICRISAT SMIP, 2663 finger millet accessions were evaluated and characterized at Aisleby, Zimbabwe. Two-hundred and thirty-five diverse accessions representing all areas growing finger millet were identified for inclusion in the working collection. Thirty-three accessions were selected for use in diversifying the genetic base through pedigree breeding, and 5 accessions are being used to create new genetic variability through mutation breeding. One accession, SDFM 723 of Indian origin, has consistently produced the highest grain yield across locations in Zimbabwe over the last four rainy seasons and is likely to be released after tests in the 1991/92 season.

## Forages

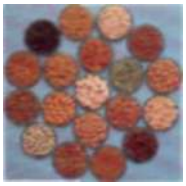
A forage pearl millet composite has been constituted by recombining 3S accessions. This composite is being improved by following reciprocal recurrent phenotypic selection. There are many brown midrib genes in sorghum, two of which are associated with reduced lignin content and an increase in digestibility by up to 20%. An active source of brown midrib in four sorghums from Malawi, and one in pearl millet from Zimbabwe germplasm were identified by the SADCC/ ICRISAT SMIP. These sources are now being backcrossed into 10 agronomically superior pearl millet varieties and 12 sorghum varieties to improve the digestibility of crop residues, and into forage sorghum and pearl millet types. The 19 selected forage sorghum accessions have been crossed into two brown midrib/juicy lines for genetic diversification.

Forty-nine napier grass accessions have been collected, and over 200 pearl millet x napier grass interspecific hybrids generated. Selection was done not only to improve dry matter production but also to increase the protein content of such crosses. Improved varieties yield 30-40% more dry matter and 2-4% (9% vs 11-13%) more protein than the local control presently cultivated by farmers.

*Pearl millet x napier grass interspecific hybrids generated at SADCC/ICRISAT SMIP, Zimbabwe.*

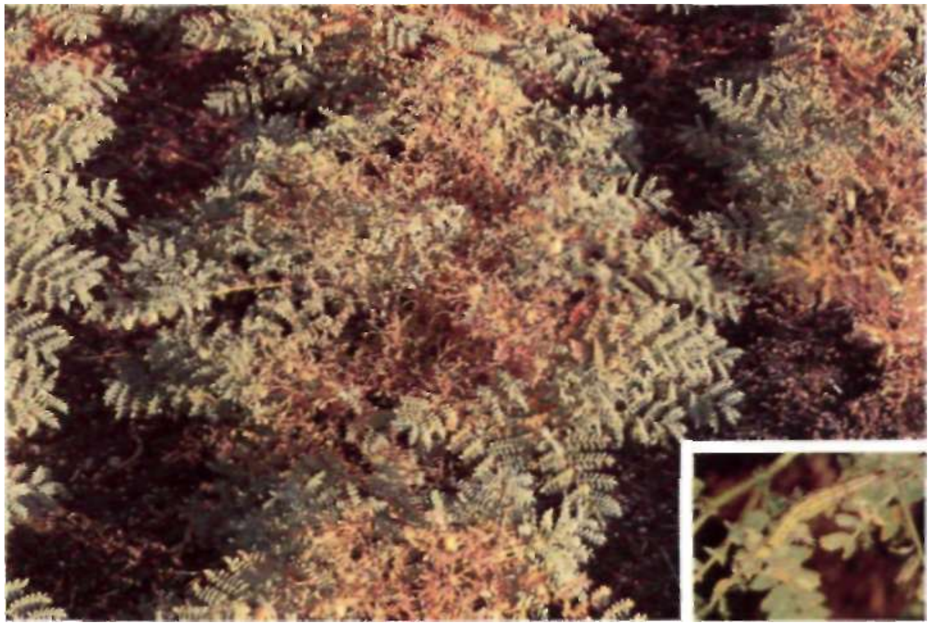
# Chickpea

## Germplasm Evaluation



At ICRISAT Center, 2739 accessions were sown for morphoagronomic evaluation. Germplasm accessions were also screened for resistance to fusarium wilt (*Fusarium oxysporum*), ascochyta blight (*Ascochyta rabiei*), stunt (bean leaf roll virus), and collar rot (*Sclerotium rolfsit*) diseases; for resistance to pod borer (*Helicoverpa armigera*); and for grain quality traits. Jointly with the Indian NARSs, ICRISAT evaluated 1000 germplasm accessions for agronomic performance at the NBPGR Regional Station, Akola, and the Directorate of Pulses Research, Kanpur. Six accessions, ICC 2043, ICC 4278, ICC 4951, ICC 12979, ICC 14348, and ICC 15559, that have superior agronomic performance and produce high biomasses were identified.

At SADCC/ICRISAT SMIP, 250 diverse chickpea accessions were sown to evaluate the potential of the crop in the region and to explore its possible introduction into Zimbabwe. Results indicate that chickpea is a potentially interesting crop for the country. The four best accessions (ICC 1713, ICC 9668, ICC 10544, and ICC 12480) produced estimated seed yields of 3.24-3.90 t/ha comparable to the best yields obtained elsewhere.



*Chickpea plants attacked by pod borer* (Helicoverpa armigera). (Inset) *A close up of the insect pest.*

*Field Day participants looking at chickpea germplasm under evaluation for agronomic performance by NBPGR and ICRISAT at the NBPGR Regional Station, Akola, India.*

## Germplasm Enhancement

Germplasm enhancement is important for ascochyta blight resistance. Chickpea plants are being screened at ICRISAT Center in a large growth room, where the temperature is maintained at 20+1 "C and the relative humidity is kept close to 100%. Around 70000 plants, under a severe selection pressure of about 1 in 10000, have been screened to date.

A similar study was conducted to select for resistance to *Helicoverpa* pod borer, an alarming insect pest of many crops. The first chickpea $F_3$ populations were screened during the 1991/92 postrainy season without pesticides and with the *Helicoverpa* population artificially augmented.

# Pigeonpea

## Germplasm Collection and Evaluation

The total ICRISAT gene bank collection from 54 countries rose to 11637 with the addition of 155 accessions during the year. Among these, 53 samples were collected from Sri Lanka, and most were of the wild species, *Cajanus* and *Rhynchosia,* on the verge of extinction in that country.

In a collaborative project with NBPGR 200 medium-duration accessions were evaluated. Further, 766 accessions were characterized for morphoagronomic traits and 720 accessions rejuvenated for long-term conservation at ICRISAT Center and for their duplicate conservation in the NBPGR gene bank, New Delhi.

*Pigeonpea germplasm Field Day at ICRISAT Center.*

## Germplasm Enhancement

As a result of joint efforts with the national program of Kenya, three pigeonpea lines that significantly outyielded all the best local controls were identified. These lines have all the desirable vegetable-type characteristics, and have shown consistency of performance over several years. Seed of purified germplasm and the data of the joint evaluation were transferred to Malawi for utilization by ICRISAT'S new Pigeonpea Improvement Program there.

### Hybrid Pigeonpea

The Varietal Release Committee of the All India Coordinated Pulses Improvement Program released ICPH S, a hybrid for cultivation in peninsular India, opening a new chapter in genetic improvement of the crop. This hybrid has given 30-40% more yield in trials conducted in India over 6 years (1981/82 to 1987/88 postrainy seasons) than local controls.

### Resistance to *Helicoverpa* Pod Borer and Podfly

Pod-boring insects, are one of the main causes of yield reduction in pigeonpea, causing losses ranging from 20% to 72%. After several years of screening under pesticide-free conditions, eight genotypes with tolerance of *Helicoverpa* pod borer and nine with tolerance of podfly (*Melanagromyza obtusa*) have been identified at ICRISAT Center. The level of resistance in these sources is low, so efforts are in progress to increase the gene frequency in populations that have resistance.

### Combined Resistance to Fusarium Wilt and *Helicoverpa* Pod Borer

In medium-duration pigeonpea, fusarium wilt (*Fusarium udum*) and *Helicoverpa* are the major yield reducers. One-hundred and thirty-Gve progenies were evaluated for yield, fusarium wilt, and *Helicoverpa* tolerance in a combined wilt and *Helicoverpa* screening nursery at ICRISAT Center. During the 1990/91 crop season, the natural incidence of *Helicoverpa* was quite high. Of the progenies evaluated, 8 were identified with less than 20% wilt infection and some resistance to *Helicoverpa.* The yield of these progenies ranged between 0.55 t/ha and 1.42 t/ha compared to complete loss of yield in the control.

### Cleistogamous Trait

Natural outcrossing (average 20%) is mainly responsible for the genetic deterioration of pure-line pigeonpea cultivars. At ICRISAT Center, a line was identified with a floral modification, that restricts outcrossing to the very low level of 2.9%. During 1991, the stability of this trait was studied in diverse environments. It was observed that outcrossing in this material was indeed very low at Modipuram (0.4%) and Hisar (0.2%) in India, and at Maha Illuppallama (0.4%) in Sri Lanka. This trait is now being transferred into elite short-, medium-, and long-duration genotypes.

# Groundnut

## Germplasm Collection and Evaluation

The total accessions in the ICRISAT gene bank rose to 13158 with the addition of 998 accessions during the year.

In collaboration with NBPGR, 300 accessions were evaluated in India at Junagadh, Akola, and ICRISAT Center.

During the year, % accessions from Uganda and 40 accessions from India, were collected. A list of groundnut germplasm accessions identified at ICRISAT Center as sources of resistance to different biotic and abiotic stresses and for nutritive quality was distributed to potential users. Diskettes with passport information and evaluation data were sent to ISC, the SADCC/ ICRISAT Groundnut Project, based at Chitedze Agricultural Research Station, Malawi, and to ICRISAT's collaborators in the USA and Australia.

*Collecting groundnut germplasm in Uttar Pradesh, India.*

The protocol for in vitro germination of excised embryos from mature seeds was established to enable possible embryo conservation. Preliminary electrophoretic studies show that there are no differences in the seed-storage protein profiles of viable and nonviable seeds. Groundnut proteins, therefore, appear to be stable and can be used for taxonomic purposes.

### Rosette Resistance Found in an ICRISAT Line

Rosette virus disease resistance has been found under severe disease pressure in a line developed at ICRISAT Center.

At the SADCC/ICRISAT Groundnut Project, groundnut rosette virus disease was uniformly severe this year throughout the experimental nursery. Most test lines showed 100% disease incidence. Only one among the 1130 entries evaluated showed a high degree of resistance. This entry originated from a complex, interspecific cross, developed by the Legumes Cell Biology Unit at ICRISAT Center and included genes from the wild species *Arachis chacoense* from central South America.

This line could become an excellent source material to broaden the genetic base of rosette resistance, especially in Africa.

### Evaluation of South American Germplasm

At the SADCC/ICRISAT Groundnut Project, 500 accessions of South American germplasm, originating from environmental conditions similar to those of SADCC countries, were evaluated. In a preliminary trial, 32 high-yielding lines and 17 lines with resistance to early leaf spot (*Cercospora arachidicola*) disease were identified.

## Germplasm Enhancement

The Groundnut Improvement Program at ISC concentrated on introducing suitable lines into western Africa; identifying the major constraints to production; identifying sources of resistance to major diseases; using parents in hybridization; and selecting early-maturing genotypes with limited seed dormancy and acceptable levels of drought tolerance.

For research on disease resistance, priority is given to early and late leaf spots (*Phaeoisariopsis personata*) and rust (*Puccinia arachidis*). There has been progress in the identification of sources of resistance to these diseases.

Data from 'hot-spots' in western Africa show that several germplasm lines are highly resistant to rust and that some give higher yields than susceptible local cultivars. These broadly resistant lines are being used in crossing blocks as sources of resistance to rust.

Following screening, cultivars 55-437, 796, and WB-9 were identified as having tolerance to drought and heat. These are also being used as parents in the hybridization program.

' Since 1988, ICRISAT has been collaborating with NARSs in western Africa in the evaluation of breeding and germplasm lines. As a result, one line, ICGS114, was released in Ghana as Sinkarzei in 1989. At present, several varieties are undergoing on-farm testing in Guinea (ICGV 86016, ICGV 86013, ICGV 86053, and ICGV 86117) and Gambia [ICGS (E) 52]. Eight ICRISAT-bred lines were entered in the Sierra Leonian national trials in 1990.

At ICRISAT Center, attempts are being made to combine resistance genes for major stress factors, i.e., rust, late leaf spot, *Aspergillus flavus,* bud necrosis disease, *Spodoptera,* leaf miner (*Aproaerema modicella*), and drought, into early-, medium-, and late-maturing oil and confectionery varieties. Multiple disease and insect pest resistant varieties such as ICGV 86031 and ICGV 86590 have been developed.

## Conservation Highlights

Long-term germplasm conservation facilities, where accessions can be safely conserved for more than 50 years, were formally inaugurated on 10 May at ICRISAT Center.

A computer-based Gene Bank Information System (GBIS) has been developed to handle the germplasm conservation data. GBIS facilitates easy storage, processing, and retrieval of information relating to the stored germplasm.

During 1991, 2873 accessions of ICRISAT mandate crops were processed and transferred to long-term conservation at -20 'C, thus increasing the base collection to 9602 accessions. A Memorandum of Understanding (MOU), under finalization, between the Indian Council of Agricultural Research (ICAR) and ICRISAT, will enable ICAR to conserve a duplicate set of pigeonpea germplasm accessions at the National Bureau of Plant Genetic Resources (NBPGR) gene bank in New Delhi.

Processing germplasm for storage (left) in the long-term gene bank (above).

## Seed Distribution

Each year, in response to seed requests, germplasm samples are supplied for utilization in ICRISAT crop improvement programs and to national agricultural research systems (NARSs) worldwide. This year 14706 samples were supplied to ICRISAT programs and 22043 to NARSs by the Genetic Resources Unit (GRU) alone.

ICRISAT breeders also supplied seeds of improved materials on request to NARS scientists.

- Sorghum breeders at SADCC/ICRISAT SMIP supplied 2519 samples of breeders' seed, breeding lines, trials and nurseries to 11 countries including Peru and Russia. Of these, 2240 samples (216 kg) were sent to Jamaica.
- Pearl millet breeders at SADCC/ICRISAT SMIP supplied 20 breeding lines and 1659 trials, and nurseries to Zimbabwe, the main recipient among 14 countries. Other recipients included Germany, Mali, Namibia, Sudan, and USA.
- Swaziland received 5.2 kg each of forage pearl millet genotypes SDMV 89102 and SDMV 89107, and Zimbabwe, 6.8 kg of SDMV 89101 from the SADCC/ICRISAT SMIP breeders. Zimbabwe also received over 20 kg of forage sorghum seed, mainly of genotypes SDFS 103 and SDFS 173.
- The largest quantities of pigeonpea seed (over 830 kg) from breeders at ICRISAT Center were dispatched to Indian NARS. Tliis was followed by Australia (200 kg) and Laos (159 kg). The most popular line requested was ICPL 87.
- India received over 4150 kg of chickpea seed from ICRISAT Center breeders. Vietnam, Thailand, and Bhutan were the other major beneficiaries. The largest supplies were of ICCC 37, ICCC 42, ICCV 10, ICCV 6, and ICCV 88202.
- The breeders at the SADCC/ICRISAT Groundnut Project supplied six trials to Botswana, Lesotho, Malawi, Namibia, Zambia, and Zimbabwe; segregating populations to Botswana, Namibia, Mozambique, Zambia, Zimbabwe, and the ICRISAT Sahelian Center; and two nurseries to Mozambique, Swaziland, and Zambia. The largest requests were for ICGMS 42 (from Uganda, Swaziland, and the EARCAL Program), ICCV 86016, JL 21, and ICGX-SM 86016/3.
- India received 493 finger millet germplasm lines from ICRISAT/SADCC SMIP. Other NARS recipients from SMIP were Malawi, Tanzania, Zambia, and Zimbabwe.

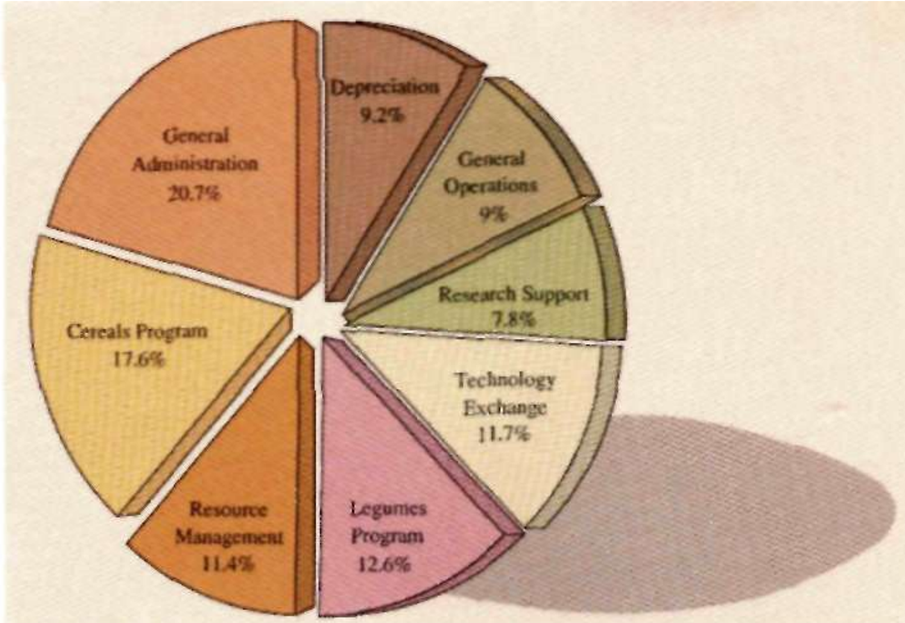
# Appendices

*Harvested groundnuts at Anantapur, India.*

# Financial Highlights

## Donor Contributions: for Core and Complementary Projects, 1991

| | U.S.S ('000) |
|---|---|
| African Development Bank | 194 |
| Asian Development Bank | 552 |
| Australia | 588 |
| Belgium | 174 |
| Canada/Canadian International Development Agency (CIDA) | 2 709 |
| China | 30 |
| Deutsche Cesellschaft fur Technische Zusammenarbeit (GTZ) | 1 971 |
| European Economic Community | 3 203 |
| Finland | 1 111 |
| France | 527 |
| Germany | 556 |
| India | 125 |
| International Fund for Agricultural Development (1FAD) | 360 |
| Italy | 410 |
| Japan | 3360 |
| Korea | 50 |
| Mexico | 10 |
| Netherlands | 1058 |
| Nigeria | 10 |
| Norway | 701 |
| Organisation of Petroleum Exporting Countries (OPEC) | 30 |
| Sweden | 805 |
| Switzerland | 1 514 |
| United Kingdom | 1 650 |
| United Nations Development Programme | 1 740 |
| United States Agency for International Development (USAID) | 8805 |
| World Bank | 2792 |
| Other complementary projects | 249 |
| Total | 35 284 |




*ICRISAT's resource allocations (core operations).*

## Balance Sheet

U.S.S ('000)

| | | 1991 | | 1990 |
|---|---|---|---|---|
| Assets | | 73 300 | | 76 053 |
| Cash and short-term deposits | | 7634 | | 8 621 |
| Accounts receivable | | 12 394 | | 11 136 |
| Inventories | | 526 | | 528 |
| Prepaid expenses | | 327 | | 702 |
| Property, plant, and equipment | 75 052 | | 75 433 | |
| Less:accumulated depreciation | 22 633 | 52 419 | 20 407 | 55 026 |
| Currency translation adjustment (net) | | - | | 40 |
| Liabilities | | 15 314 | | 16 181 |
| Accounts payable and other liabilities | | 9204 | | 9 951 |
| Overdrafts with banks | | 50 | | 25 |
| Accrued salaries and benefits | | 3 508 | | 4 120 |
| Payments in advance from donors | | 2475 | | 2085 |
| Currency translation adjustment (net) | | 77 | | - |
| Fund balances | | 57 986 | | 59 872 |
| Capital | | 52 419 | | 55 026 |
| Capital replacement fund | | 3044 | | - |
| Special purpose fund | | 207 | | 231 |
| Unexpended funds | | 2 316 | | 4 615 |
| Total liabilities and fund balances | | 73 300 | | 76 053 |

A. F. FERGUSON & CO.
CHARTERED ACCOUNTANTS
ALLAHABAD BANK BUILDINGS
BOMBAY SAMACHAR MARG
BOMBAY 400001

No. ACG/1961 March 30, 1992

The Governing Board,
International Crops Research Institute
for the Semi-Arid Tropics
Patancheru (A.P.)

Dear Sirs,

Report on the Audit of the Financial Statements
for the year ended December 31, 1991.

We have completed our examination of the books of account of the Institute for the year ended December 31, 1991 and enclose the Statement of Financial Position, Statement of Activity, Statement of Activity by Funding Source and Statement of Changes in Financial Position, duly signed by us under reference to this report.

2. Scope of Audit

Our examination of the above Statements included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances. We have broadly reviewed the systems and procedures relating to accounting, internal control and maintenance of books and records. The audit was carried out in accordance with generally accepted auditing standards in India. Our examination was made primarily for the purpose of forming our opinion on the Financial Statements taken as a whole.

The reports on the accounts of the Institute's project in the Southern African Development Coordination Conference (SADCC) region, Zimbabwe, and the ICRISAT Sahelian Center, in Niamey, Niger, audited by other auditors, have been produced to us and have been considered in preparing our report.

3. Effect of Change in the Institute's Accounting Policies

The Institute has, with effect from 1991, introduced depreciation accounting in accordance with the guidelines laid down by the Consultative Group on International Agricultural Research (CGIAR). This has had an adverse impact on the result disclosed in the Statement of Activity for the year to the extent of US $ 2,833 thousand (refer note 1.4 to the Financial Statements).

4. Opinion

In our opinion, the Statement of Financial Position as on December 31, 1991, Statement of Activity, Statement of Activity by Funding Source and Statement of Changes in Financial Position for the year ended as on that date, present fairly, subject to and on the basis of the accounting policies set out in note 1 to the Financial Statements and read with the other notes thereon, the financial position of the Institute as on that date and the changes in its financial position for the year then ended, in conformity with accounting principles consistently applied except as described in paragraph 3 above. We further report that the above Statements are in accordance with the books and records of the Institute and the information and explanations furnished to us.

5. We record, with pleasure, our appreciation of the cooperation rendered to us by the Director General and the staff during the course of the audit.

Yours faithfully,

# ICRISAT in Print

*Each entry has been classified by program under the research activity of the first ICRISAT author. Research Support includes general publications. Order copies from Information Services, ICRISAT Center, by the catalog codes, or JA/CP number, given in parentheses at the end of each entry.*

## Cereals

### *Publications from ICRISAT*

**Maiti, R.K., and Bisen, S.S. 1990.** L'anatomie du mil *[Pennisetum glaucum* (L.) R.Br.]. Information Bulletin no. 6. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics. 24 pp. ISBN 92-9066-192-5. *(*IBF 006*)*

**Murty, D.S. (ed.). 1991.** L'utilisation industrielle du sorgho: comptes rendus d'un Colloque sur l'etat actuel et le potentiel des utilisations industrielles du sorgho au Nigeria, 4-6 decembre 1989, Kano, Nigeria. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics. 72 pp. ISBN 92-9066-204-2. (CPF 065)

### *Publications in the International Scientific Press*

**Bandyopadhyay, R., Mughogho, L.K., Satyanarayana, M.V., and Kalisz, M.E. 1991.** Occurrence of airborne spores of fungi causing grain mould over a sorghum crop. Mycological Research 95(11):1315-1320. (JA 1185)

**Fussell, L.K., Bidinger, F.R., and Bieler, P. 1991.** Crop physiology and breeding for drought tolerance: research and development. Field Crops Research 27:183-199. (JA 1025)

**Gupta, S.C, Lambert, A., and Ndoye, A.T. 1991.** Registration of 'ICMV 2' pearl millet. Crop Science 31(5):1382. (JA 1026)

**Gupta, S.C, and Ndoye, A.T. 1991.** Yield stability analysis of promising pearl millet genotypes in Senegal. Maydica 36:83-86. (JA 1013)

**Jain, R.P., Chavan, S.B., Talukdar, B.S., and Andrews, D.J. 1991.** Registration of 'ICMS 7703' pearl millet. Crop Science 31(5):1381-13S2. (JA 744)

**Knepper, D., Tunde Obilana, A., and Musselman, L.J. 1991.** Morphology of *Striga forbesii* and preliminary screening for resistance in sorghum. Pages 241-246 *in* Proceedings of the 5th International Symposium of Parasitic Weeds, 24-30 Jun 1991, Nairobi, Kenya

*Discussing ICRISAT publications.*

**(Ransom, J.K., Musselman, L.J., Worsham, A.D., and Parker, C, eds.).** Nairobi, Kenya: International Maize and Wheat Improvement Center (CIMMYT). (CP 683)

**Kretzschmar, R.M., Hafner, H., Bationo, A., and Marschner, H. 1991.** Long and short term effects of crop residues on aluminum toxicity, phosphorus availability and growth of pearl millet in an acid sandy soil. Plant and Soil 136(2):215-223. (JA 1137)

**Mahalakshmi, V., Bidinger, F.R., and Raju, D.S. 1991.** Effect of drought stress during grain filling in near-isogenic tall and dwarf hybrids of pearl millet (*Pennisetum glaucum*). Journal of Agricultural Science, Cambridge 116:67-72. (JA 993)

**Matthews, R.B., Azam-Ali, S.N., Saffell, R.A., Peacock, J.M., and Williams, J.H. 1991.** Plant growth and development in relation to the microclimate of a sorghum/groundnut intercrop. Agricultural and Forest Meteorology 53:285-301. (JA 1101)

**Nwanze, Kanayo F. 1991.** Components for the management of two insect pests of pearl millet in Sahelian West Africa. Insect Science and its Application 12(5/6):673-678. (CP 543)

**Nwanze, Kanayo F. 1991.** Sustainable food production in Africa: the challenge to national agricultural research systems (NARS). Insect Science and its Application 12(5/6):615-625. (CP 687)

**Nwanze, K.F., Kokubu, H., and Teetes, G.L. 1991.** Insect pests of sorghum and their control. Pages 66-76 *in* Proceedings of the 11th International Congress of Plant Protection: Focus on the developing world, 5-9 Oct 1987, Manila, Philippines (Magallona, E.D., ed.). Vol II. Los Banos, Philippines: Organizing Committee, 11th ICCP, University of Philippines. (CP 415)

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**Nwanze, K.F., Reddy, Y.V.R., Taneja, S.L., Sharma, H.C., and Agrawal, B.L. 1991.** Evaluating sorghum genotypes for multiple insect resistance. Insect Science and its Applications 12(1-3): 183-188. (CP 542)

**Osman, M.A., Raju, P.S., and Peacock, J.M. 1991.** The effect of soil temperature, moisture and nitrogen on *Slriga asiatica* (L.) Kuntze seed germination, viability and emergence on sorghum (*Sorghum bicolor* L. Moench) roots under field conditions. Plant and Soil 131:265-273. (JA 1014)

**Pande, S., Mughogho, L.K., Bandyopadhyay, R., and Karunakar, R.I.1991.** Variation in pathogenicity and cultural characteristics of sorghum isolates of *Colletotrichum graminicola* in India. Plant Disease 75(8):778-783. (JA 971)

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## - as of 31 Dec 1991

(The countries of internationally recruited staff are italicized.)

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Stanley B. King, *USA,* Principal Pathologist
Kanayo F. Nwanze, *Nigeria,* Principal Entomologist
Carlos S. Busso, *Italy,* Associate Principal Cell Biologist
H. Frederick W. Ratrunde, *USA,* International Associate Scientist
Eva Weltzien Ratrunde, *Germany,* International Associate Scientist
Belum V.S. Reddy, Senior Breeder
K.N. Rai, Senior Breeder
B.S. Talukdar, Breeder
N. Seetharama, Senior Physiologist (*on sabbatical leave from Oct*)
V. Mahalakshmi, Physiologist
P. Soman, Physiologist (*on lean until Jan*)
S.D. Singh, Senior Pathologist
R.P. Thakur, Senior Pathologist
Suresh Pande, Pathologist
Ranajit Bandyopadhyay, Pathologist (*on sabbatical leave from Aug*)
S.L. Taneja, Entomologist
H.C. Sharma, Entomologist

Cooperative Cereals Research Network (CCRN)

Chandra M. Pattanayak, *India,* Principal Coordinator (*on study leave from May*)
G. Alagarswamy, Physiologist

Eastern Africa Regional Cereals and Legumes (EARCAL) Program, Kenya

Vartan Y. Guiragossian, *France,* SAFGRAD/ICRISAT Coordinator for Sorghum and Millet, Eastern Africa (on *study leave from Aug*)
Samwiri Z. Mukuru, *Uganda,* Principal Sorghum Breeder

#### Latin American Sorghum Improvement Program (LASIP), Mexico

Compton L. Paul, *Guyana,* Team Leader and Principal Sorghum Agronomist
C Thomas Hash, Jr., *USA,* Principal Sorghum Breeder (*until Jan*)
Rene Clara V, *El Salvador,* Associate Sorghum Breeder

Appendices

## Legumes

### Program Office

Duncan McDonald, *UK,* Program Director

### Crops Research

Hendrikus A. van Rheenen, *Netherlands,* Principal Chickpea Breeder (*on study leave until Oct*)
Rasiah P. *Ariyanayagam, Sri Lanka,* Principal Pigeonpea Breeder
Shyam N. Nigam, *India,* Principal Groundnut Breeder
J.P. Moss, *UK,* Principal Cell Biologist (*on study leave during Feb-Aug*)
Chris Johansen, *Australia,* Principal Agronomist
Osamu Ito, *Japan,* Principal Agronomist and Team Leader, Government of Japan Special Project
Donald H. Smith, *USA,* Principal Pathologist
D.V.R. Reddy, *India,* Principal Virologist
John A. Wightman, *UK,* Principal Entomologist (on *study leave trom Dec*)
Michel P. Pimbert, *France,* Principal Entomologist (*until Oct*)
Nigel J- Amies, *UK,* Principal Entomologist, ICRISAT/XRI
Nico Horn, *Netherlands,* Assistant Virologist
K.K. Sharma, *India,* International Associate Scientist, Cell Biology (from Sep)
Said N. Silim, *Uganda,* International Associate Scientist (Crop Physiology) (*until* Off)
Ryoichi Matsunaga, J*apan,* Associate Principal Physiologist
Jagdish Kumar, Senior Chickpea Breeder *{on leave from Sep)*
Onkar Singh, Senior Chickpea Breeder
*S.C. Sethi, Senior* Chickpea *Breeder* (Hisar)
K.B. Saxena, Senior Pigeonpea Breeder
S.C. Gupta, Senior Pigeonpea Breeder (OH *leave from Jul)*
N.B. Singh, Visiting Scientist *{on ad hoe assignment from Sep)*
K.C. Jain, Pigeonpea Breeder
L.J. Reddy, Senior Groundnut Breeder
S.L. Dwivedi, Groundnut Breeder
H.D. Upadhyaya, Groundnut Breeder (*from Feb*)
D.C. Sastri, Cell Biologist (*until May*)
Nalini Mallikarjuna, Cell Biologist (*from Apr*)
N.P. Saxena, Senior Physiologist (*on secondment until Nov, followed by sabbatical leave)*
O.P. Rupela, Physiologist
K.R. Krishna, Physiologist
YS. Chauhan, Physiologist
V.M. Ramraj, Physiologist
R.C. Nageswara Rao, Physiologist (*on sabbatical leave until Jun*)
M.P Ha ware, Senior Pathologist
M.V. Reddy, Senior Pathologist
A.M. Ghanekar, Pathologist (*until May*)
V.K. Mehan, Pathologist
S.B. Sharma, Nematologist
S.S. Lateef, Senior Entomologist
G.V. Ranga Rao, Entomologist

### Asian Grain Legumes Network (AGLN)

Donald G. Faris, *Canada,* Principal Coordinator
C.L.L. Gowda, Senior Breeder
J.V.D.K. Kumar Rao, Physiologist, LECOFTEN
C.S. Pawar, Entomologist, LEGOFTEN

### EARCAL Program. Kenya

Laxman Singh, *India,* Principal Pigeonpea Agronomist
5aid *N.* Silim, *Uganda,* Associate Principal Agronomist *(from Oct)*

ICARDA, Syria

K.B. Singh, *India,* Principal Chickpea Breeder

## Resource Management

### Program Office

John L. Monteith, *UK,* Program Director (until *Nov)*
R.S. Aiyer, Assistant Manager (Administration)

### Agronomy

S.M. Virmani, *India,* Principal Agroclimatologist
Chin K. Ong, *Malaysia,* Principal Agronomist (*until Apr*)
David J. Flower, *Australia,* Principal Physiologist (*from Oct upon transfer*)
David R. Butler, UK, Principal Microclimatologist
Merle M. Anders, USA, Principal Production Agronomist
Piara Singh, Senior Soil Scientist
A.K.S. Huda, Agroclimatologist (until *Mar*)
A. Ramakrishna, Agronomist
Madhukar V. Potdar, Agronomist
P. Mohan Rao, Scientist (GIS) (*from Apr*)
A.A.H. Khan, Senior Engineer (Research Support)
S.K. Sharma, Senior Research Associate

### Soil

John R. Burford, *Australia,* Principal Soil Chemist
Kofi B. Larvea, *Ghana,* Principal Soil Physicist
Donald F. Yule, *Australia,* Principal Soil Scientist, ICRISAT/QDPI (*until fan*)
Alexander L. Cogle, *Australia.* Principal Soil Scientist, 1CRISAT/QDPI (*from Jan*)
Keuk-Ki Lee, *Korea,* Principal Microbiologist
Adolf Schiitt, G*ermauy,* Assistant Principal Engineer (*until Dec*)
K.L. Sahrawat, Senior Soil Scientist (*on leave from Aug*)
T.J. Rego, Senior Soil Scientist
Sardar Singh, Soil Scientist
Prabhakar Pathak, Agricultural Engineer
N.K. Awadhwal, Agricultural Engineer/ Soil Physicist (on *leave until Oct)*
Suhas P. Wani, Microbiologist
K.P.C. Rao, Soil Scientist (*from Feb*)

### Economics

Thomas S. Walker, USA, Principal Economist *(until Mar)*

Timothy G. Kelley, USA, Principal Economist (*from Oct*)
John M. Kerr, *USA,* Assistant Principal Economist
John H. Foster, USA, Visiting Economist *{until Aug)*
Meri L. Whitaker, *USA,* International Associate Economist
R.P. Singh, Economist
K. Rama Devi, Economist (fram *Oct*)

### ICRISATILCA Joint Vertisol Project (Ethiopia)

K.L. Srivastava, *India,* Principal Soil and Water Engineer

## Support Programs

### Computer Services

James W. Estes, *USA,* Head
S.M. Luthra, Manager
J. Sai Prasad, Assistant Manager
T.B.R. Nagendra Gupta, Senior Programmer/Analyst

### Crop Quality Unit

R. Jambunathan, *USA,* Principal Biochemist and Program Leader
Umaid Singh, Biochemist
V. Subramanian, Biochemist

### Electron Microscope Unit

A.K. Murthy, Senior Engineer

### Farm Development and Operations

D.S. Bisht, *India,* Manager
Shiva K. Pal, Senior Plant Protection Officer
K. Ravindranath, Senior Engineer (Farm Machinery)
Ramesh C. Sachan, Senior Engineer
Marri Prabhakar Reddy, Senior Agricultural Officer
M.C. Ranganatha Rao, Senior Engineer
N.V. Subba Reddy, Senior Horticultural Officer

### Genetic Resources Unit

Melak H. Mengesha, *Ethiopia,* Principal Germplasm Botanist and Program Leader
K.E. Prasada Rao, Senior Germplasm Botanist
R.PS. Pundir, Senior Germplasm Botanist
S. Appa Rao, Senior Germplasm Botanist
P. Remanandan, Germplasm Botanist
A.K. Singh, Germplasm Botanist
5urendra Mohan, Senior Administrative **Officer *{until Aug)***

### Housing and Food Services

David A. Evans, *UK,* Head
Samiran Mazumdar, Assistant Manager (Housing and Food Services)
B.R. Revathi Rao, Assistant Manager (Housing) (*on leave from Sep*)
D.V. Subba Rao, Assistant Manager (Housing and Warehouse)

### Human Resource Development Program

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

### Information Services

J. Brian Wills, *UK,* Head
Susan D. Hall, *UK,* Research Editor *{on study leave until Jun)*
Eric M. McGaw, *USA,* Research Editor
Princess I. Ferguson, USA, Visiting **Editor *{until May)***
S.M. Sinha, Assistant Manager (Art and Production)
Jugu J. Abraham, Editor
V, Sadhana, Editor
Deepak Macherla, Editor *(from Apr)*
Gopal K. Guglani, Senior Art Visualizer
T.R. Kapoor, Senior Supervisor (Composing)
Upendra Ravi, Videographer *(from Feb upon transfer*)

P. Subrahmanyam, Senior Administrative Officer (*until Mar*)

### Library and Documentation Services

L.J. Haravu, Manager *(on leave until Sep)*
P.K. Sinha, Senior Documentation Officer; Manager (Acting) *(until Sep)*
PS. Jadhav, Senior Library Officer
S. Prasannalakshmi, Senior Library Officer

### Physical Plant Services

Vincent P. McGough, *UK,* Manager *(on study leave from Aug)*
D. Subramaniam, Manager (Acting) *(on leave from Feb to Jul)*
D.C. Raizada, Senior Engineer; Chief Engineer (Acting) *(from Feb to Jul)*
N.S.S. Prasad, Senior Engineer
A.N. Singh, Senior Engineer
K. Ramesh Chandra Bose, Senior Engineer
S.P. Jaya Kumar, Senior Administrative Officer *(on leave from Nov)*

### Plant Quarantine Unit

N.C Joshi, Chief Plant Quarantine Officer (*on ad hoc assignment until May)*
A.M. Ghanekar, Plant Quarantine Officer (*from Jun upon transfer*)
Upendra Ravi, Senior Research Associate (*until Jan*)

### Radio Isotope Laboratory

S. Sivaramakrishnan, Biochemist

### Statistics

K. Vidyasagar Rao, Senior Statistician (*on ad hoc assignment from Oct*)

Appendices

# West African Programs

## ICRISAT Sahelian Center (ISC), Niger

### Administration

Ronald W. Gibbons, *UK,* Executive Director, West African Programs, and Director, ISC

Alieu M.B. Jagne, *Gambia,* Regional Administrator

K.P. Xair, *India,* Regional Purchase and Supplies Manager (*until Jan*)

CO. Coovi, *Benin,* Regional Purchase and Supplies Manager (*from Aug*)

M.S. Diolombi, *Niger,* Regional Finance Officer (*from Oct*)

K.A. Moussa, *Niger,* Personnel Officer

G. Ouoba, *Burkina Faso,* Chief, Computer Services Unit

P. Falzon, *France,* Regional Housing and Food Services Officer (*from Nov*)

### Research Programs

#### Pearl Millet Improvement

K. Anand Kumar, *India,* Principal Breeder and Team Leader *(on Study leave until Jul*)

Shadrach O. Okiror, *Uganda,* Principal Breeder and Regional Trials Officer

Ousame Youm, *Senegal,* Associate Principal Entomologist

Dale E. Hess, *USA,* Associate Principal Pathologist

P. Soman, *India,* Principal Agronomist (*until Ian*)

W.A. Payne, USA, Physiologist *(from Apr)'*

S. Tostain, *France,* Principal Geneticist (ORSTOM) *(until Nov)*

J.F. Renno, *France,* Principal Geneticist (ORSTOM)

#### Groundnut Improvement

Bruno J. N'dunguru, *Tanzania,* Principal Agronomist and Team Leader

Farid Waliyar, *France,* Principal Pathologist

B.R. X'tare, *Uganda,* Principal Breeder (*from Jan*)

#### Resource Management

Charles Renard, *Belgium,* Principal Agronomist and Team Leader

Jonathan H. Williams, *Zimbabwe, Principal* Physiologist

Michiel C. Klaij, *Netherlands,* Principal Soil and Water Management Scientist *(on study leave until Sep)*

M.V.K. Sivakumar, *India,* Principal Agroclimatologist

Jojo Baidu-Forson, *Ghana,* Principal Economist

Rick J. Van Den Beldt, *USA,* Principal Agronomist/Agroforester (*until Jul*)

J. Brouwer, *Netherlands,* Principal Soil Scienist, Agricultural University of Wageningen/ICRISAT

J.C. Weber, *USA,* Forest Geneticist (ICRAF) (*from Oct*)

Andre Bationo, *Burkina Faso,* Principal Soil Chemist (IFDC)

Jane C. Hopkins, *USA,* Visiting Scientist (IFPRI) (*until Sep*)

M. Welte, *Germany,* Program Coordinator, University of Hohenheim

Jane Toll, *UK,* IBPGR Coordinator for West Africa

M. Powell, *USA,* Principal Agroecologist (ILCA)

T.O. Williams, *Nigeria,* Principal Economist (ILCA)

S. Fernandez-Rivera, *Mexico,* Principal Nutritionist (ILCA) (*from May*)

#### Support

A.R. Das Gupta, *India,* Manager, Physical Plant Services

Bruno Gerard, *Belgium,* Farm Manager (*from Sep*)

Roberta H. Gottfried, *USA,* Regional Information Officer (*from Sep*)

John Q.H. Nguyen, *USA,* Principal Training Officer

Roger D. Stern, *UK,* Principal Statistician

## WASIP-Mali

### Administration

S.N. Lohani, *Nepal,* Principal Breeder and Team Leader

R. Vaidvanathan, *India,* Administrative Officer

### Research

Melville D. Thomas, Sierra *Leone,* Principal Sorghum Pathologist and SAFCRAD/ICRISAT Coordinator

S.K. Debrah, *Ghana,* Economist (*from Sep*)

P. Salez, *France,* Principal Agronomist and IRAT Team Leader

C. Luce, *France,* Principal Sorghum Breeder (IRAT)

A. Ratnadass, *France,* Principal Sorghum Entomologist (IRAT)

G. Hoffmann, *France,* Principal *Striga* Agronomist (CIRAD)

## Mali Bilateral Program

S.V.R. Shetty, *India,* Principal Agronomist and Team Leader (until *May, subsequently on study leave)*

## WASIP-Nigeria

### Administration

Olupomi Ajayi, *Nigeria,* Principal Sorghum Entomologist and Team Leader

A. Banerji, *India,* Administrative Officer

### Research

D.S. Murty, *India,* Principal Sorghum Breeder

Ramadjita Tabo, *Chad,* Principal Agronomist

David J. Rower, Australia, Principal Physiologist *(until Oct)*

# Southern African Programs

## SADCC/ICRISAT Sorghum and Millets Improvement Program (SMIP), Zimbabwe

Leland R. House, *USA,* Executive Director, Southern Africa, and Project Manager, SADCC/ICRISAT SMIP
Alfred Schulz, *USA,* Regional Administrative Officer
Anthony B. Ohilana, *Nigeria,* Principal Sorghum Breeder
Subhash C. Gupta, *India,* Principal Forages and Millet Breeder
Walter A.J. de Milliano, *Netherlands,* Principal Cereals Pathologist *(until May)*
Mahmood Osmanzai, *Afghanistan,* Principal Cereals Agronomist
Klaus Leuschner, *Germany,* Principal Cereals Entomologist
David D. Rohrbach, *USA,* Principal Economist
Henrv Ssali, *Uganda,* Soil Scientist (IFDC)
Manel I. Gomez, Sri *Lanka,* Principal Food Technologist
Chibhamu M. Matanyaire, *Zimbabwe,* Principal Station Management and Development Officer
Lovegot Tendengu, *Zimbabwe,* Regional Training Officer
Nurdin S. Katuli, *Tanzania,* Station Development and Management Officer
Emmanuel S. Monyo, *Tanzania,* Regional Pearl Millet Breeder
Nathaniel Mwamuka, *Zimbabwe,* Farm Manager
Richard Nxumalo, Accounts/ Personnel Officer
Tenson Dube, Senior Research Technician (Sorghum)
Fungai Munaku, Senior Research Technician (Agronomy)
Murairo Madzvamuse, Laboratory Technician (Food Technology)
Sanders Mpofu, Senior Research Technician (Millet)

## SADCC/ICRISAT Groundnut Project, Malawi

Gerhard Schmidt, *Germany,* Team Leader
Geoff L, Hildebrand, *Zimbabwe,* Principal Breeder
Pala Subrahmanyam, *India,* Principal Pathologist
V.S. Swaminathan, *India,* Administrative Officer *(until Oct)*
Morgan Mukonde, *Zambia,* Administrative Officer (*from Jul*)

## ICRISAT Pigeonpea Project

Solomon Tuwafe, *Ethiopia,* Associate Principal Pigeonpea Breeder *{from*

# Postdoctoral Fellows and Research Scholars

# ICRISAT Center

### Cereals

Frauke Wehmann, *Germany,* Postdoctoral Fellow
Jose Antonio Sifuentes, *Mexico,* Postdoctoral Fellow
Alan Thomas, *UK,* Postdoctoral Fellow
Fabrice Pinard, *France,* Postdoctoral Fellow *(until Sep)*
Sujata, *India,* Postdoctoral Fellow *(from Feb)*
Lawrence T. Ogunremi, *Nigeria,* Senior Research Fellow *(from May)*
Adeyinka Adenrele Adesivun, *Nigeria,* Senior Research Fellow *(from May to Dec)*
Abdin Mohamed Zein-el-abdin, *Sudan,* Senior Research Fellow *(from Jul to Sep)*
Fathy Ibrahim Hassan El-Attar, *Egypt,* Senior Research Fellow *(from Sep to Oct)*
Kobaisi Kassem Mohamed, *Egypt,* Senior Research Fellow *(from Nov to Dec)*
Mahmoud Fadl El Mula Ahmed, *Sudan,* Research Fellow (*until Feb*)
Leopoldo Mendoza-Onofre, *Mexico,* Research Fellow *(from Jan to Mar)*
Kadiatou Toure, *Mali,* Research Fellow *(from Feb to Apr)*
I. Eltayeb F.Itohami, *Sudan,* Research Fellow *(from Feb to May)*
Jose Jorge G.T. Aguirre, *Mexico,* Research Fellow *(from Aug to Nov)*
Mohsin Mohamed Mansoor, *Yemen,* Research Fellow (*from Sep to Nov*)
Celia V. Chalam, *India,* Research Scholar
Mahad Abdi Farah, *Somalia,* Research Scholar
Tag Elsir Bashir, *Sudan,* Research Scholar
Poranki Swarna Sree, *India,* Research Scholar *(until Aug)*
Mohamed Hassan Aden, *Somalia,* Research Scholar *(until Nov)*
Peter James Lynch, *USA,* Research Scholar *(until Dec)*
K. Vijayalakshmi, *India,* Research Scholar (*from Oct*)
Ahmed Saeed Awadh Binseewad, *Yemen,* Research Scholar *(from Dec)*

### Legumes

Francois Xavier Poul, *France,* Postdoctoral Fellow
Satoshi Tobita, *Japan,* Postdoctoral Fellow
A. Srinivasan, *India,* Postdoctoral Fellow *(until May)*
R.V. Satyanarayana Rao, *India,* Postdoctoral Fellow (*from Jan*)
M.K. Naik, *India,* Postdoctoral Fellow *(from Jan)*
Edward P. Broglio, *USA,* Postdoctoral Fellow *(from Feb)*
Shiv Kumar, *India,* Postdoctoral Fellow *(from Feb)*
M. Satya Prasad, *India,* Postdoctoral Fellow *(from Mar)*
Mohinder Singh, *India,* Postdoctoral Fellow (*from Apr*)
P.P. Zaveri, *India,* Senior Research Fellow (*from May*)
K.K. Zote, *India,* Senior Research Fellow (*from Dec*)
Osmund Mwandemele, *Tanzania,* Senior Research Fellow (*from Jul to Aug*)
Ramesh K. Gumber, *India,* Research Fellow *(until May)*

Appendices

Nguyen Xuan Hong, *Vietnam,,* Research Fellow (*from Aug*)
Siti Zinab Ramawas, *Malaysia,* Research Fellow (*Mar*)
B.S. Sosroprawiro, *Indonesia,* Research Fellow (*from Aug to Nov*)
Damodara Sreedhar, *India,* Research Fellow (*Sep*)
Dnyanoba Dhondiram Nirmal, *India,* Research Fellow (*Oct*)
Iskander A. Yousuf, *Yemen,* Research Fellow (*from Oct to Nov*)
L.C. Wijetilaka, *Sri Lanka,* Research Fellow (*Nov*)
B. Regunathan, Sri *Lanka,* Research Fellow (*Dec*)
Chintapalli Prasannalatha, *India,* Research Scholar
K. Vijaya Lakshmi, *India,* Research Scholar
Anne Aloysia Maria Buiel, *Netherlands,* Research Scholar
Zakia Ibrahim Ali, *Sudan,* Research Scholar
Telugu Uma Maheswari, *India,* Research Scholar *(until Dec)*
Nguyen Hai Nam, *Vietnam,* Research Scholar *(from Apr)*
Susan Varshadhara Wesley, *India,* Research Scholar (*from May*)
V. Anitha Reddy, *India,* Research Scholar (*from Sep*)
Suresh V. Naik, *India,* Research Scholar *(from Sep)*
Christiane Dorothea Weigner, *Germany,* Research Scholar *(from Oct)*
Elke Hartlie, *Germany,* Research Scholar *(from Oct)*
G.M.W. Chithral, *Sri Lanka,* Research Scholar *(from Oct)*

### Resource Management

Peter Parviz Motavalli, *USA,* Postdoctoral Fellow *(until Jun)*
Thippareddy Bapi Reddy *India,* Postdoctoral Fellow (*until Nov*)
Ashok Kumar Patra, *India,* Postdoctoral Fellow *(from fan)*
N. Vidyalakshmi, *India,* Postdoctoral Fellow (*from Feb*)
George J. Ley, *Tanzania,* Postdoctoral Fellow (*from Aug*)
Abdel Moneium Mohamed Eltilib, *Sudan,* Senior Research Fellow (*from May to Jun*)
Edgar F. Padilla, *Philippines,* Research Fellow (*from Apr*)
Suwasik Karsono, *Indonesia,* Research Fellow (*from Jun to Sep*)
Stephan Singer, *Germany,* Research Scholar
Radha Ranganathan, *India,* Research Scholar
S. Ravi Kumar, *India,* Research Scholar
Mohamed Dayib Sh. Abdurahman, *Somalia,* Research Scholar
R. Lakshminarayanan, *India,* Research Scholar (*until May*)
Fiona Margaret Marshall, UK, Research Scholar (*until May*)
Ajay Kumar, *India,* Research Scholar (*until May*)
G.W.L. Jayakumar, *India,* Research Scholar (*until Dec)*
Roshan M. Bajracharya, *Nepal,* Research Scholar (*from jun*)
M. Nivedita, *India,* Research Scholar (*from Aug*)
G. Sujatha, *India,* Research Scholar (*from Aug*)
Alka Dhirendra Parikh, *India,* Research Scholar (*from Nov*)
Elasha Abdelhay Elasha, *Sudan,* Research Scholar (*from Dec*)
John Leonard Pender, *USA,* Research Scholar (*from Jan to Jun*)
Ashley Amanda Bell, *UK,* Research Scholar (*from May to Nov)*

### Crop Quality Unit

Basilius A. Susila Santosa, *Indonesia,* Research Fellow (*from Jan to Apr*)
Y.S. Sailaja, *India,* Research Scholar (*from Mar*)

### Genetic Resources Unit

Adib Sultana, *India,* Research Scholar

## ICRISAT Sahelian Center

### Resource Management Program

Carl Daamen, UK, Postdoctoral Fellow (*until Nov*)
Zana Sonda, *Burkina Faso,* Postdoctoral Fellow, ILCA (*from Dec*)
Felix Ikpe, *Nigeria,* Research Fellow, ILCA
Axel Hebel, *Germany,* Research Fellow (until *Jan*)
Suzan Hoefs, *Germany,* Research Fellow, ILCA (*until Apr*)
Christophe Kouame, *Cote d'lvoire,* Research Fellow, ILCA *(until May)*
Karl Michels, *Germany,* Research Fellow (*until Oct*)
John Lamers, *Netherlands,* Research Fellow (*from Apr*)
Andreas Buerkardt, *Germany,* Research Fellow (*from May*)
Martina Mayus, *Germany,* Research Fellow *(from Jun)*
Hermann Ludger, *Germany,* Research Fellow *(from Sep)*
Sadri Fian, *Germany,* Research Fellow *(from Oct)*
Katiella Mai Moussa, *Niger,* Research Fellow *(until Jul)*
Helen Steward, *UK,* Research Fellow *(from May)*
Marianne Glynn, *UK,* Research Fellow *(from Aug)*
Mariano Cabezas, *Spain,* Research Fellow (*Feb-Apr*)

### Groundnut Improvement Program

Hans Peter Rebafka, *Germany,* Research Fellow (*until Oct*)

### Pearl Millet Improvement Program

Peter Bieler, *Switzerland,* Research Fellow
Birgit Piro, *Gennany,* Research Fellow (*Jun-Sep*)

# Awards and Distinctions

- Leslie D. Swindale, Director General, was awarded the Indian Government's civilian award 'Padma Bhushan' by the President of India. He was also the recipient of a golden *Ciwara* (Grand Cultivator) from the national and international agricultural researchers of Mali.

- Yeshwant L. Nene, Deputy Director General, was conferred the honorary degree of Doctor of Science in recognition of his 'singular contribution to the cause of agricultural research, education, and development' by the G.B. Pant University of Agriculture and Technology, L'ttar Pradesh, India.

- Vartan Guiragossian, Semi-Arid Food Grain Research and Development (SAFGRAD)/ICRISAT Regional Coordinator for Eastern Africa, Eastern Africa Regional Cereals and Legumes (EARCAL) program, Kenya, received a meritorious award for outstanding and dedicated effort on food grain research and coordination in eastern Africa during the Organization for African Unity (OAU)-SAFGRAD Inter-Network Conference on Food Grain Research and Production in Semi-Arid Africa, held at Niamey, Niger.

- Melville D. Thomas, Principal Sorghum Pathologist, West African Sorghum Improvement Program (WASIP)-Mali, was chosen by the same conference, to receive a meritorious award for outstanding and dedicated effort and cooperation with national and regional programs in food grain research and improvement in West Africa.

- Ranajit Bandyopadhyay, Plant Pathologist, Cereals Program, ICRISAT Center, was awarded the Second Annual 'Frosty' Hill Fellowship for 1991, at Cornell University, USA. This award was instituted in honor of the cofounder of the Consultative Group on International Agricultural Research (CGIAR) System, Dr Forest F. 'Frosty' Hill, and is awarded competitively to one scientist from the CGIAR-supported or affiliated international centers.

- Donald H. Smith, Principal Plant Pathologist, ICRISAT Center, received the first Coyt T. Wilson Distinguished Service Award for his services to the American Peanut Research and Education Society (APRES) in various capacities over the last several years.

- Olupomi Ajayi, Principal Cereals Entomologist and Team Leader, WASIP, Nigeria, received the De-Lima Award for Scientific Merit for his paper 'Possibilities for integrated control of the millet stem borer, *Acigona ignefusalis* Hampson (Lepidoptera: Pyralidae) in Nigeria' from the African Association of Insect Scientists, in a meeting held at Legon, Accra, Ghana.

- Melak H. Mengesha, Program Leader, Genetic Resources Unit, ICRISAT Center, was appointed *to* the Technical Advisory Board *of* the Southern African Development Coordination Conference (SADCC) Regional Gene Bank for a 4-year term by the Southern African Centre for Cooperation in Agricultural Research (SACCAR).

- ICRISAT Research Highlights 1989, a publication from Information Services, ICRISAT Center, was awarded a First Place in the 'Four Color Special Report' category at the annual Critique and Awards Program of the Agricultural Communicators in Education (ACE), USA.

# Important Visitors

## ICRISAT Center, India

| | |
|---|---|
| 8 Feb | Don Heflin, Vice Consul, U.S. Consulate, Madras, India |
| 21 Feb | Jean Pierre Zehnder, Ambassador of Switzerland in India |
| 21 Feb | V.S. Shevelukha, V.I. Lenin All-Union Academy of Agricultural Science (VASKHNIL), Moscow, Commonwealth of Independent States (CIS); and A. Dragavtsev, Director, N.I. Vavilov Institute of Plant Industry, Leningrad, CIS |
| 4 Mar | Krishan Kant, Governor of Andhra Pradesh, India |
| 18 Mar | K. Eshmirzaev, Director, Research Institute of Grains and Pulses, Samarkand, CIS |
| 22 Mar | Prem Chand Jaidas, High Commissioner of Trinidad and Tobago in India |
| 3 Apr | William Clark Jr., Ambassador of USA in India |
| 11 Jul | Sahadou Bawa, Director General, Instirut national de recherches agronomiques du Niger (INRAN), Niamey, Niger |
| 15 Jul | M.V. Rao, Vice Chancellor, Andhra Pradesh Agricultural University, Hyderabad, India |
| 4 Oct | David Evans, High Commissioner of Australia in India |
| 11 Oct | L.L. Mehrotra, Secretary, Ministry of External Affairs, Government of India, New Delhi |

## ICRISAT Sahelian Center, Niger

| | |
|---|---|
| 27 Feb | Ali Sabou, President of Niger; and Adamou Souna, Minister of Agriculture, Niger |
| 21 Mar | Irfan-ur-Rehman Raja, Charge d'affaires, Embassy of Pakistan |
| 11 Jul | Margaret Rothwell, Ambassador of UK to Cote d'Ivoire and Niger |
| 11 Sep | Mouhamad-Mach'Houd Kelani, Ambassador of the Republic of Benin in Niger |
| 11 Oct | M.P. Sedogo, Director General, Centre national de recherche scientifique et technique, Burkina Faso |

## SADCC/ICRISAT SMIP, Zimbabwe

| | |
|---|---|
| 23 Mar | Martin Kyomo, Executive Secretary, Southern African Centre for Cooperation in Agricultural Research (SACCAR), Botswana |
| 14 Jun | David Karimanzira, Minister of Agriculture, Zimbabwe |

## WAS IP-Mali

| | |
|---|---|
| 14 Feb | Moulaye Mohamed Haidara, Minister of Agriculture, Mali |
| 13 Dec | Henri Carsalade, Director General, Centre de cooperation internationale en recherche agronomique pour le developpement (CIRAD), France. |

# Agreements Signed by ICRISAT

During 1991, six Memoranda of Understanding that will strengthen research cooperation between ICRISAT and the following organizations and institutes were signed:

- **Caribbean Agricultural Research and Development Institute (CARDI),** Trinidad, West Indies, on 16 May.
- **International Centre of Insect Physiology and Ecology (ICIPE),** Nairobi, Kenya, on 17 June.
- **Malaysian Agricultural Research and Development Institute (MARDI)** of the Ministry of Agriculture, Selangor, Malaysia, on 18 June.
- **Andhra Pradesh Agricultural University (APAU),** Hyderabad, India, on 15 July.
- **International Irrigation Management Institute (IIMD,** Colombo, Sri Lanka, on 9 August.
- **Swiss Development Cooperation (SDC),** Switzerland, on 27 August.

*ICRISAT Director General L.D. Swindale* (left) *and Vice Chancellor M.V. Rao of Andhra Pradesh Agricultural University signing the Memorandum of Understanding on 15 July.*

# ICRISAT Plant Material that Reached Farmers' Fields

**Cumulative list of releases of ICRISAT plant material and NARS plant material using ICRISAT germplasm, up to December 1991.**

| ICRISAT name/Source/ Parenl/Pedigree | Other name's | Release name | Remarks |
|---|---|---|---|
| **Sorghum** | | | |
| Sel. from crosses from Chapingo | | Centa S-2 | Released cultivar in El Salvador (1976) |
| Sel. from crosses from E. Africa | | Valles Altos 110 | Released cultivar in Mexico (1978) |
| ATx623 x Sweet Sudan | | Centa SS-41 (forage) | Released cultivar in El Salvador (1980) |
| A 6072 | | Yuan 1-54 | Released cultivar in China (1982) |
| A 3681 | | Yuan 1-98 | Released cultivar in China (1982) |
| A 3872 | | Yuan 1-28 | Released cultivar in China (1982) |
| A 3895 | | Yuan 1-505 | Released cultivar in China (1982) |
| Hageen Durra 1 | | Hageen Durra 1 | Released hybrid in Sudan (1982)<br>Male sterile parent, ATx623 from Texas A&M University. Pollinator, Karper 1597 from ICRISAT,' |
| Sel. from M 91057 | | 1S1AP Dorado<br>Blanco Sb | Released cultivar in El Salvador (1983)<br>Released cultivar in Mexico (1986) |
| Scl. from CS 35-11 | | Tortillero 1 | Released cultivar in Honduras (1984) |
| ATx623 x Torlillero 1 | | Catracho | Released cultivar in Honduras (1984) |
| ICSV 2 | SPV 386 | ZSV 1 | Released cultivar in Zambia (1983) |
| IS 9302 | IS 9302 | ESIP 11 | Released cultivar in Ethiopia (1984) |
| IS 9323 | IS "323 | ESIP 12 | Released cultivar in Ethiopia (1984) |
| ICSV 1 | SPV 351 | CSV 11<br>SPV 351 | Released cultivar in India (1984)<br>Released cultivar in Malawi (1989) |
| M 90906 | Schwe phyu 1 | Yezin 1 | Released cultivar in Mvanmar (1984) |
| M 36248 | Schwe phyu 2 | Yezin 2 | Released cultivar in Mvanmar (1984) |
| M 36335 | Schwe phyu 3 | Yezin 3 | Released cultivar in Mvanmar (1984) |
| M 36172 | Schwe phyu 4 | Yezin 4 | Released cultivar in Mvanmar (1984) |
| ICSV 112 | SPV 475 | SV 1<br>UANL-I-187<br>CSV 13<br>Pacifico 301<br>Pinolero I | Released cultivar in Zimbabwe (1987)<br>Released cultivar in Neuvo Leon, Mexico (1987)<br>Released cultivar in India (1988)<br>Released cultivar in Mexico (1990)<br>Released cultivar in Nicaragua (1990) |
| M 62650 | | Sureno | Released cultivar in Honduras (1985) |
| SEPON 177 | | Niea-sor (T 43) | Released cultivai in Nicaragua (1985 |
| M 90975 | ICTA C-21 | ICTA Mitlan 85 | Released cultivar in Guatemala (1985) |
| ICSH 153 | SPH 221 | CSH 11 | Released hvbrid in India (1986) Male-sterile parent 296A from AICSIP. Pollinator MR 750 from ICRISAT. |
| M 90362 | | UANL-I-287 | Released cultivar in Neuvo Leon, Mexico (1987) |
| AGROCONSA 1 | | AGROCONSA I | Released hybrid in El Salvador (1987) Male sterile parent ATx625 from Texas A&M University. Pollinator M 90362 from ICRISAT. |

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Appendices

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| ICRISAT name/Source/ Parent/Pedigree | Other namc/s | Release name | Remarks |
|---|---|---|---|
| ICSV 88060 | | SV 2 | Released cultivar in Zimbabwe (1987) |
| ICSV 145 | SPV 694 | SAR 1 | Resistant to *Striga asiatiai* in India. Recommended for cultivation in Striga-endemic areas of India, except Karnataka state (1988) |
| Liao Hybrid no. 4 | | Liao Hybrid no. 4 | Released hvbrid in China (198S). Male sterile parent SPL 132 A from ICRISAT. Pollinator from China. |
| M 62641 | | Costeno 201 | Released cultivar in Mexico (1989) |
| SDS 3220 | | Macia | Released cultivar in Mozambique (1989) |
| IS 8571 | | Mamonhe | Released cultivar in Mozambique (1989) |
| WSV 387 | | Kuvuma | Released cultivar in Zambia (1989) |
| WSV 187 | | Sima | Released cultivar in Zambia (1989) |
| IS 2391 | | SDS 1513 | Released cultivar in Swaziland (1989) |
| IS 3693 | | SDS 1594-1 | Released cultivar in Swaziland (1989) |
| E 1966 | IS 30468 | NTJ2 | Pure line selection from a germplasm line released in Andhra Pradesh, India for postrainy season cultivation (1990) |
| ICSV 1007 HV | SRN 39 | Mugawim Buda 1 | Released in Sudan for *Striga hermonthica* endemic rainfed, mechanized fanning areas. It has a broad-spectrum resistance throughout the *Striga*-infested areas of the world (1991) |
| IS 9830 | | Mugawim Buda 2 | Released in Sudan for *Striga hermonthica* endemic rainfed farming conditions (1991) |
| M 91057 | 1CTA C-25 | Istmeno | Released cultivar in Mexico (1991) |
| PP 290 | | Perlita | Released cultivar in Mexico (1991) |
| Sel. from M 90362 | | Escameka | Released cultivar in Costa Rica (1991) |
| Sel. from ISIAP Dorado | | Alanje Blanquito | Released cultivar in Panama (1991) |
| **Pearl Millet** | | | |
| Serere Composite 2 | | L'gandi | Released in Sudan (1981) Developed at Serere station, Uganda; introduced into Sudan bv ICRISAT |
| ICMV 1 | WC-C75 | WC-C75 | Released cultivar in India (1982)<br>Released cultivar in Zambia (1987) |
| ICMV 4 | MP 15 | ICMS 7703 | Released cultivar in India (1985) |
| ICMV 5 | ITMV 8001 | ITMV 8001 | Released cultivar in Niger (1985) |
| ICMV 6 | ITMV 8002 | ITMV 8002 | Released cultivar in Niger (1985) |
| ICMV 7 | 1TMV 8304 | ITMV 8304 | Released cultivar in Niger (1985) |
| ICMH 451 | MH 179(ICH 451) | ICMH 451 (MH 179) | Released hvbrid in India (1986) |
| ICMH 501 | MH 180(ICH 501) | ICMH 501 (MH 180) | Released hvbrid in India (1986) |
| ICMH 423 | MH 143 (ICH 423) | ICMH 423 | Released hvbrid in India (1986) |
| ICMA 1<br>ICMB 1 | 81A<br>81B | | Released seed parent of hvbrid ICMH 451 in India (1986) |
| ICMA 4<br>ICMB 4 | 834 A<br>834 B | | Released seed parent of hybrid ICMH 501 in India (1986) |
| ICTP 8203 | ICTP 8203 | MP 124<br><br>Okashana 1<br>PCB 138 | Released cultivar in Maharashtra and Andhra Pradesh states, India (1988)<br>Released cultivar in Namibia (1989)<br>Released cultivar in Punjab state, India (1989) |

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| ICRISAT name/Source/ Parent/Pedigree | Other name/s | Release name | Remarks |
|---|---|---|---|
| ICMA 2<br>ICMB 2 | 843 A<br>843 B | | Released seed parent of hybrid HHB 67 in India (1989) |
| ICMB 841 | ICMB 841 | ICMB 841 | Released seed parent of hybrids Pusa 23 and ICMH 423 in India (1988) |
| ICMA 841 | ICMA 841 | ICMA 841 | Released seed parent of hybrids Pusa 23 and ICMH 423 in India (1988) |
| ICMV 82132 | | Kaufela<br>IKMV 8201 | Released cultivar in Zambia (1989)<br>Released cultivar in Burkina Faso (1991) |
| ICMV 155 | ICMV 84400, MP 155 | ICMV 155 | Released cultivar in India (1991) |
| Late Backup Composite | | Lubasi | Released cultivar in Zambia (1991) |
| **Finger Millet** | | | |
| IE 2929 | | Lima | Released cultivar in Zambia (1989) |
| **Chickpea** | | | |
| ICC 8521 | | Aztec | Released cultivar in USA (mid 1980s) |
| ICCV 1 | ICCC 4 | ICCC 4<br>Sita | Released cultivar in Gujarat state, India (1983)<br>Released cultivar in Nepal (1987) |
| Sel. from ICC 12366 | JG 62 x F 496 | RSG 44 | Released cultivar in India (1984) |
| Sel. from ICC 14302 | F 378 x F 404 | Anupam | Released cultivar in India (1984) |
| Sel. from L 550 x L 2 | | GNC 149 | Released cultivar in India (1985) |
| ILC 72 (ICARDA) | | Fardan<br>Califfo | Released cultivar in Spain (1985)<br>Released cultivar in Italy (1987) |
| ILC 200 (ICARDA) | | Zegri<br>Atalaya | Released cultivar in Spain (1985)<br>Released cultivar in Spain (1985) |
| ILC 2548 (ICARDA) | | Almena | Released cultivar in Spain (1985) |
| ILC 2555 (ICARDA) | | Alcazaba | Released cultivar in Spain (1985) |
| FLIP 83-16C (ICARDA) | | Kassab | Released cultivar in Tunisia (1986) |
| Be-sel-81-48 (ICARDA) | | Amdoun 1 | Released cultivar in Tunisia (1986) |
| ILC 195 (ICARDA) | ILC 195 | ILC 195<br>ILC 195 | Released cultivar in Turkey (1986)<br>Released cultivar in Morocco (1987) |
| ILC 482 (ICARDA) | ILC 482 | Gunev Sarisi 482<br>Ghab 1<br>ILC 482<br>ILC 482<br>TS 1009<br>Janta 2<br>Jubeiha 2<br>ILC 482 | Released cultivar in Turkey (1986)<br>Released cultivar in Syria (1986)<br>Released cultivar in Morocco (1987)<br>Released cultivar in Algeria (1988)<br>Released cultivar in Franco (1988)<br>Released cultivar in Lebanon (1989)<br>Released cultivar in Jordan (1990)<br>Released cultivar in Iraq (1991) |
| ILC 3279 (ICARDA) | ILC 3279 | Yialousa<br>Chetoui<br>Ghab 2<br>Sultano<br>ILC 3279<br>Jubeiha 3<br>ILC 3279 | Released cultivar in Cyprus (1984)<br>Released cultivar in Tunisia (1986)<br>Released cultivar in Syria (1986)<br>Released cultivar in Italy (1987)<br>Released cultivar in Algeria (1988)<br>Released cultivar in Jordan (1990)<br>Released cultivar in Iraq (1991) |
| ICCL 83110 | | ICCL 83110 | Released cultivar in Kenya (1986) |
| Sel. from K 850 x F 378 | | Schwe Kvehmon | Released cultivar in Myanmar (1986) |
| ICC 552 | P436 | Yezin 1 | Released cultivar in Myanmar (1986) |

*continued...*

Appendices

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| ICRISAT name/Source/ l'arent/l'edigree | Other name/s | Release name | Remarks |
|---|---|---|---|
| ICCL 81248 | | Nabin | Released cultivar in Bangladesh (1987) |
| ILC 464 (ICARDA) | ILC 464 | Kyrenia | Released cultivar in Cyprus (1987) |
| ILC 1335 (ICARDA) | | Shendi | Released cultivar in Sudan (1987) |
| ICC 6098 | JG 74 | Radha | Released cultivar in Nepal (1988) |
| Sel. from 850-3/27 x F 378 | | Mariye | Released cultivar in Ethiopia (1988) |
| ILC 202 (ICARDA) | | ILC 202 | Released cultivar in China (1988) |
| ILC 411 (ICARDA) | | ILC 411 | Released cultivar in China (1988) |
| FLIP 81-293C (ICARDA) | | TS 1502 | Released cultivar in France (1988) |
| ILC 237 (ICARDA) | | ILC 237 | Released cultivar in Oman (1988) |
| ICCV 2 | ICCL 82001 | Swetha | Released in Indian states of Andhra Pradesh, (1989), Maharashtra (1991) |
| ICCC 37 | ICCL 80074 | Kranthi | Released cultivar in Andhra Pradesh state, India (1989) |
| ILC 5566 (ICARDA) | | Elmo | Released cultivar in Portugal (1989) |
| FLIP 85-17C (ICARDA) | | Elvar | Released cultivar in Portugal (1989) |
| ICCV 6 | ICCC 32 | Kosheli | Released cultivar in Nepal (1990) |
| ICCL 82108 | | Kalika | Released cultivar in Nepal (1990) |
| FLIP 85-7C (ICARDA) | | Damla 89 | Released cultivar in Turkey (1990) |
| FLIP 85-135C (ICARDA) | | Tasova 89 | Released cultivar in Turkey (1990) |
| RIP 84-79C (ICARDA) | FLIP 84-79C | RIP 84-79C<br>RIP 84-79C | Released cultivar in Algeria (1991)<br>Released cultivar in Tunisia (1991) |
| FLIP 84-92C (ICARDA) | FLIP 84-92C | RIP 84-92C<br>RIP 84-92C<br>RIP 84-92C | Released cultivar in Algeria (1991)<br>Released cultivar in Morocco (1991)<br>Released cultivar in Tunisia (1991) |
| RIP 82-150C (ICARDA)<br>87AK71115 | | Ghab 3<br>Akcin | Released cultivar in Syria (1991)<br>Released cultivar in Turkey (1991) |
| **Pigeonpea** | | | |
| Prabhat x Baigani | QPL 1<br>Hunt | Hunt<br>Mocha | Released cultivar in Australia (1983)<br>Released cultivar in Indonesia (1987) |
| ICPV 1 | ICP 8863 | Maruti | Released cultivar in Kamataka state, India (1985) |
| T21 x JA 277 | QPL 42 | Quantum | Released cultivar in Australia (1985 |
| ICP 7035 | | Kamica | Released cultivar in Fiji (1985) |
| ICPL 87 | | Pragati<br>ICPL 87 | Released cultivar in India (1986)<br>Released cultivar in Mvanmar (1990) |
| ICP 9145 | ICP 9145 | Nandolo Wansawara | Released cultivar in Malawi (1988) |
| Sel. from (Prabhat x HY 3C) x (ICP 7018 x ICP 7035) | | Quest | Released cultivar in Australia (1988) |
| ICPL 151 | | Jagriti | Released cultivar in India (1989) |
| ICPL 332 | | Abhava | Released cultivar in India (1989) |
| ICPH 8 | | ICPH 8 | Released hybrid in India (1991) |
| **Groundnut** | | | |
| Sel. from ICGS 1 | | Spring Groundnut '84<br>Konkan Gaurav | Released cultivar in Punjab state, India for spring cultivation (1984)<br>Released cultivar in Maharashtra state, India (1991) |
| JL 24 | | Sinpadetha 2 | Released cultivar in Myanmar (1984/85) |

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| ICRISAT name/Source/ Parent/Pedigree | Other name/s | Release name | Remarks |
|---|---|---|---|
| Robut 33-1 | | Sinpadetha 3 | Released cultivar in Mvanmar (1984/85) |
| Sel. from Robut 33-1 | | Johari | Released cultivar in Tanzania (1985) |
| ICGV S7123 | ICGS 11 | ICCS 11 | Released cultivar in central and peninsular India for postrainv season (1986) |
| TMV 7 x FSB 7-2 | | VRI1 | Released cultivar in Tamil Nadu state, India (1986) |
| ICC 7886 | Tifrust 2 | Cardi-Pavne | Released germplasm line in Jamaica (1987) |
| ICCV 87127 | ICGS 35 | Jinpungtangkong | Released cultivar in South Korea (1987) |
| FESR selection | | ALR 1 | Released rust-resistant cultivar in Tamil Nadu state, India (1987) |
| ICC 7794 | ICC 7794 | Roba | Released cultivar in Ethiopia (1988) |
| ICGV 87128 | ICGS 44 | ICGS 44 | Released cultivar in Gujarat state, India for postrainv season (1988) |
| (ICGV 87128+ICGV 87187) bulk | | BARD 699 | Released cultivar in Pakistan (1989) |
| ICGV 87141 | ICGS 76 | ICGS 76 | Released cultivar in states of Andhra Pradesh, Karnataka, and parts of Maharashtra and Tamil Nadu in India for rainv season (1989) |
| X 14-4-B-19-B x NC Ac 17090 | | Gimar 1 | Released cultivar in India (1989) |
| Robot 33-1 x NC Ac 2821 | | RG 141 | Released *cultivar* in Rajasthan state, India *(1989)* |
| ICGV 87119 | ICGS 1 | ICGS 1 | Released cultivar in northern India (1990) |
| ICGV 87121 | ICGS 5 | ICGS 5 | Released cultivar in U.P. state, India (1989) |
| ICGV 87187 | ICGS 37 | ICGS 37 | Released cultivar in states of Gujarat, Madhya Pradesh and northern Maharashtra, India for postrainv season (1990) |
| ICCV 87160<br>ICGMS 42 | ICG(FDRS)10 | ICG(FDRS)10<br>CG 7<br>MGS 4 | Released cultivar in peninsular zone, India, 1990<br>Released cultivar in Malawi in 1990<br>Released cultivar in Zambia in 1990 |
| ICGV 86194 | ICGS 114 | Sinkarzei | Released cultivar in Ghana (1989) |
| ICGV 86590 | | ICGV 86590 | Released cultivar in southern Maharashtra, parts of Andhra Pradesh, Tamil Nadu, Karnataka and Kerala states in India for rainy season (1991) |

**ICRISAT material not released but grown by farmers.**

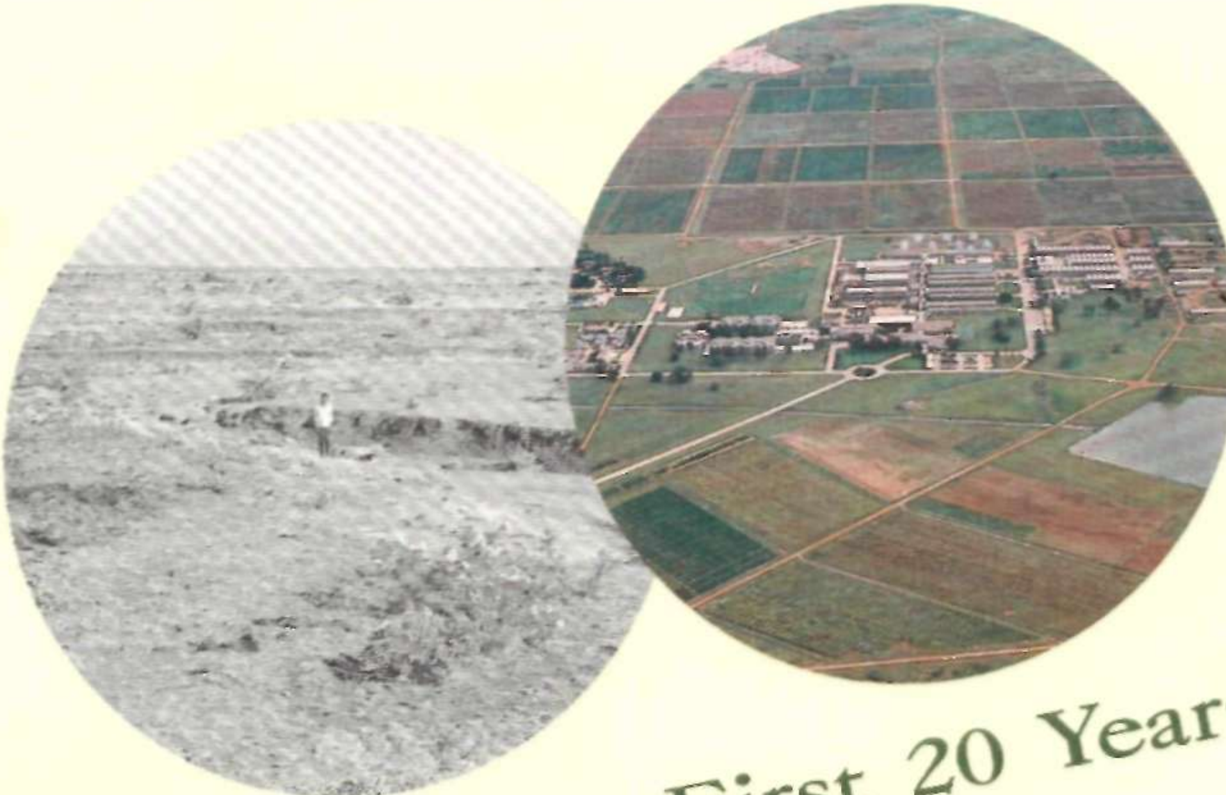
| ICRISAT name/Source/ Parent/Pedigree | Other name/s | Release name | Remarks |
|---|---|---|---|
| **Sorghum** | | | |
| ICSV 745 | | ICSV 745 | Adopted by farmers in Karnataka slate, India (1991) |
| ISIAP Dorado | | Dorado | Grown by farmers in Paraguay |
| **Pigeonpea** | | | |
| ICPL 84045 | | ICPL 84045 | Grown by farmers in Sri Lanka (1991) |
| **Groundnut** | | | |
| ICGS 21 | | ICGS 21 | Grown by farmers in Maharashtra state, India |
| ICGV 86564 | ICC(CC)49 | ICGS 49 | Grown by farmers in Maharashtra and Tamil Nadu states, India |
| ICC(FDRS) 4 | | ICG(FDRS) 4 | Grown by farmers in Maharashtra state, India |

# Acronyms

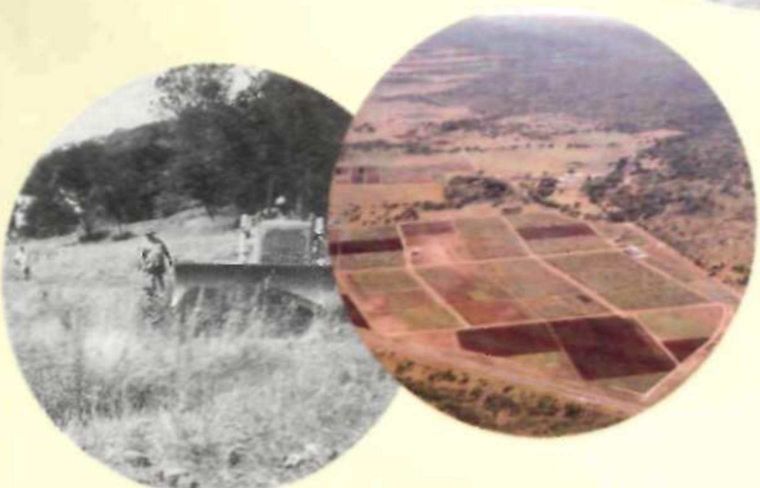
| | |
|---|---|
| ACE | Agricultural Communicators in Education (USA) |
| ACIAR | Australian Centre for International Agricultural Research |
| AEZ | agroecological zone |
| AICPMIP | All India Coordinated Pearl Millet Improvement Program |
| ADB | Asian Development Bank (Philippines) |
| AGLN | Asian Grain Legumes Network |
| AIDAB | Australian International Development Assistance Bureau |
| APAU | Andhra Pradesh Agricultural University (India) |
| APRES | American Peanut Research and Education Society |
| AUA | Alemaya University of Agriculture (Ethiopia) |
| BNV | bud necrosis virus |
| CARDI | Caribbean Agricultural Research and Development Institute (Trinidad) |
| CCRN | Cooperative Cereals Research Network |
| CE | catechin equivalents |
| CGIAR | Consultative Group on International Agricultural Research |
| CIDA | Canadian International Development Agency |
| CILSS | Comite permanent inter-Etats de lutte contre la secheresse dans le Sahel (Mali) |
| CIMMYT | Centra Intemacional de Mejoramiento de Maiz y Trigo (Mexico) |
| CIRAD | Centre de cooperation internationale en recherche agronomique pour le developpement (France) |
| CIS | Commonwealth of Independent States |
| CLAN | Cereals and Legumes Asia Network |
| CLAIS | Comision Latinamericana de Investigadores en Sorgo (Guatemala) |
| CRIDA | Central Research Institute for Dryland Agriculture (India) |
| DM | dry matter |
| DNA | deoxyribonucleic acid |
| EARCAL | Eastern Africa Regional Cereals and Legumes program |
| EPR | External Program Review |
| FAO | Food and Agriculture Organization of the United Nations (Italy) |
| GBIS | gene bank information system |
| GIS | geographic information system |
| GRU | Genetic Resources Unit |
| GRV | groundnut rosette virus |
| IBSRAM | International Board for Soil Research and Management (Thailand) |
| ICAR | Indian Council of Agricultural Research |
| ICARDA | International Center for Agricultural Research in the Dry Areas (Syria) |
| ICIPE | International Centre of Insect Physiology and Ecology (Kenya) |
| IER | Institut d'economie rurale (Mali) |
| IFTM | Instron Food Testing Machine |
| IIM1 | International Irrigation Management Institute (Sri Lanka) |
| 1LCA | International Livestock Centre for Africa (Ethiopia) |
| INERA | Institut d'etudes et de recherches agricoles (Burkina Faso) |
| INRAN | Institut national de recherches agronomiques du Niger |
| INSAH | Institut du Sahel (Mali) |
| INTSORMIL | International Sorghum/Millet, Collaborative Research Support Program (USA) |
| ISC | ICRISAT Sahelian Center |
| KARI | Kenya Agricultural Research Institute |
| LASIP | Latin American Sorghum Improvement Program |
| LGS | length of the growing season |
| MARDI | Malaysian Agricultural Research and Development Institute |
| MOU | Memorandum of Understanding |
| NARS | national agricultural research system |

| | |
|---|---|
| NBPGR | National Bureau of Plant Genetic Resources (India) |
| NRCS | National Research Centre for Sorghum (India) |
| NRI | Natural Resources Institute (UK) |
| OAU | Organisation of African Unity |
| ORSTOM | Institut francais de recherche scientifique pour le developpement en cooperation (France) |
| RFLP | restricted fragment length polymorphism |
| ROCAFREMI | Reseau ouest et centre africain de recherche sur le mil (WCAMRN) |
| RPMIS | research project management information system |
| SACCAR | Southern African Centre for Cooperation in Agricultural Research (Botswana) |
| SADCC | Southern African Development Coordination Conference (Botswana) |
| SAFGRAD | Semi-Arid Food Grain Research and Development (Nigeria) |
| SAT | semi-arid tropics |
| SCRI | Scottish Crop Research Institute (UK) |
| SDC | Swiss Development Cooperation |
| SDU | sorghum diastatic unit |
| SMIP | Sorghum and Millets Improvement Program |
| SMR | soil moisture regime |
| SR | selective ratio |
| SSQE | Sweet Sorghum Quality Evaluation |
| UNESCO | United Nations Educational, Scientific, and Cultural Organization (France) |
| USAID | United States Agency for International Development |
| VASKHNIL | V.I. Lenin All-Union Academy of Agricultural Science (CIS) |
| WANA | West Asia and northern Africa |
| WASIP | West African Sorghum Improvement Program |
| WCAMRN | West and Central African Millet Research Network (ROCAFREMI) |

**Acknowledgements: This Report was** compiled, edited, and produced by Information Services, ICRISAT. The contributions of all the Institute's scientists and support staff, particularly those who provided their photographs are gratefully acknowledged.



# ICRISAT - the First 20 Years



International
Crops Research Institute
for the Semi-Arid Tropics

# ICRISAT — the First 20 Years

This is an account of high endeavor and achievement for humanity. It was the vision of the founders of ICRISAT to improve the quality of life for the people who dwell in the semi-arid places on the edges of the world's deserts, by improving the reliability and productivity of their food crops. What has already been accomplished in the first 20 years in every part of the world, however remote, is a record of sustained commitment and hard work by ICRISAT's scientists. Their research has been conducted in cooperation with the world's farmers and agricultural research centers in harmony and friendship unmatched in the political world.

This is just the beginning. From work already in progress will emerge future harvests which will mean a better life for millions of people who might otherwise face serious food shortages.

As populations grow and more food needs to be produced to feed them, the demands for ICRISAT'.s products have become more persistent because the search for cultivable land drives farmers into the marginal semi-arid areas. Furthermore, whether as a result of use, global warming, or a temporary shortfall of rain, water tables are falling in many parts of the world. Towns and cities want more and more water, and village wells have to be dug deeper and deeper.

ICRISAT's own scientists are deeply aware of their responsibility to humanity. It is as noble a cause as can be found. The crops on which ICRISAT works are grown by resource-poor farmers in some of the world's poorest countries, and as such have not attracted the commercial research funding that has been made available to more profitable world crops. There is thus a continuing need for the finance which has been so generously provided by donors to ICRISAT.

In the 20 years since it became the first center to be founded under the aegis of the the Consultative Group on International Agricultural Research (CGIAR), ICRISAT has considerable achievements to its credit. We now have established laboratories and research stations at several locations including the Headquarters at Patancheru, Andhra Pradesh, India, the ICRISAT Sahelian Center (ISC), at Sadore near Niamey, Niger, and the SADCC/ICRISAT Sorghum and Millets Improvement Program (SMIP), at Matopos near Bulawayo, Zimbabwe (see cover photographs). At these and seven other locations our scientists and those of the national agricultural research systems (NARSs) concentrate on the basic, strategic, adaptive, and applied research needed to overcome the problems of farmers in our mandate region—the semi-arid tropics (SAT).

*This commemorative publication shows the story of our successes and our ongoing work through photographs related to each of the four clauses of our mandate and contains a 'Milestones' a on the major events of ICRISAT's history.*

*ICRISAT serves as a world center for the improvement of grain yield and quality of sorghum, millets, chickpea, pigeonpea, and groundnut and acts as a zvorld repository for the genetic resources of these crops.*

Our first priority is to act as a world repository for the genetic resources of our mandate crops; sorghum, pearl and finger millets, pigeonpea, chickpea, and groundnut and our collections have come a long way since the genebank was started with short-term storage facilities. The long-term genebank (1) was inaugurated in 1991 and we now have the world's largest collections of germplasm of our mandate crops. These include 33108 accessions of sorghum from 88 countries, 22110 accessions of pearl millet from 44 countries, 16443 accessions of chickpea from 42 countries, 11910 accessions of pigeonpea from 54 countries, 12841 accessions of groundnut from 89 countries, and 7144 accessions of minor millets from 42 countries. The genebank also holds several hundred accessions of the wild relatives of our mandate crops.

This germplasm bank has been accumulated through gifts and exchanges with many international organizations and national programs, particularly those in India, and also by our scientists traveling throughout the SAT on collection missions, in association with representatives of the national programs, with whom ICRISAT shares all its collections (2).

1

2

But none of our collection efforts would be possible without the help of the local farmers and scientists who generously share their material, e.g., when collecting chickpea in Bangladesh in 1985 (3).

Collected material is evaluated for its potential use in breeding programs. Some accessions are very valuable like the zera-zera sorghums from Ethiopia and Sudan (4) that were recently converted from photoperiod-sensitive genotypes that grow tall and do not flower in the rainy season, to photoperiod-insensitive ones that do flower after a given number of days irrespective of when they are sown. Pearl millet collected in Togo in 1989 (5) has several good agronomic traits that are now being used to improve breeding populations.

We collect as near to the centers of crop diversity as possible, e.g., pigeonpea (6) originated in India where many wild species are found. Groundnut *(Arachis)* wild species are particularly useful in crop improvement work for the disease resistance genes they confer to the cultivated species. *Arachis* material collected in Brazil in 1982 (7a) is now growing at ICRISAT Center (7b) where it was visited in 1983 by its collector.

3

7b

The collected material shows an amazing range of variability in color, shape, and maturity (8 a,b,c). It is evaluated at ICRISAT Center and jointly with our NARSs collaborators in many countries such as; pearl millet in India (9a), finger millet in Zambia (9b), and pigeonpea in Kenya (9c). The results of these evaluations yield many benefits because the material identified provides the basic 'building blocks' from which improved cultivars are developed.

8b

8c

9 b

9a

9c

*ICRISAT develops 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.*

The SAT is a harsh environment. For most of the year it is dry, but when the rains come, they often wash away precious soil (10). On soils that are not well drained, crops become waterlogged (11). Precious rainwater needs to be conserved and put to the best possible use by managing the land through a watershed approach (12) which today forms the basis of the Government of India's multi-million dollar development program. The watershed approach helps the farmer to make the best use of land relative to the growing season. Early work in Vertisol areas in India led to the development of the graded broadbed and furrow and fertility management system (13). This system involves surface draining the land sufficiently to allow two crops a year to be grown where previously farmers could only grow one because the soil was too heavy and wet to be worked in the rainy season (14). Over 10 years the average runoff of water from the traditional system was halved from 220 mm to 110 mm per hectare, meaning more soil moisture for the following crops. The broadbed and furrows if double cropped lost 1.1 t of soil per hectare per year, whilst the traditional flat system fallowed in the rainy season lost 6.6 t of soil.

Two crops a year with improved technology over 12 years yielded 3.2 t of maize or sorghum *and* 1.1 *t* of pigeonpea or chickpea per hectare but the traditional single postrainy-season crop yield was only *either* 0.6 t of sorghum *or* chickpea. This technology is now being put into practice in Ethiopia where conditions and soils are similar to those of Vertisol regions in India.

Intercropping has always been a component of many traditional farming systems (15a). Our early work on determining the best combinations of crops has helped farmers increase their yields and incomes (15b). In a long-term experiment over 8 years a cowpea/pigeonpea intercrop benefitted the succeeding cereal (sorghum) consistently by the nitrogen it added to the soil. This nitrogen was equivalent to about 40 kg of nitrogenous fertilizer per hectare. Intercropping pearl millet with cowpea has been studied at ISC from the mid 1980s (16a). In years when the rains come early, short-duration millet can be harvested while there is sufficient residual soil moisture to get a 'bonus' crop from intercropped cowpea (16b). This practice should help farmers in the Sahel to increase the sustainabilitv of their farming systems, because it provides them with both food grains to eat and fodder to maintain their livestock throughout the dry season, and the cowpea enriches the soil by fixing nitrogen.


10


11


12


13


14


15a


15b


16a


16b

17a

In the Sahel, wind erosion is a problem and wind-driven sand often buries and kills pearl millet seedlings (17a). Windbreaks have been shown (17b) to reduce soil drift. Among the tree species that can be used for windbreaks some provide fodder for livestock and domestic fuel in addition to conserving precious soil.

*ICRISAT identifies constraints to agricultural development in the semi-arid tropics and evaluates means of alleviating them through technological and institutional changes.*

Special problems restrict productivity in some areas and demand research attention for their resolution. For example, saline soils restricted chickpea growth at our Cooperative Research Station at Hisar (18). Nutrient deficiencies are serious growth-limiting factors, particularly on Alfisols in India and Africa. Acidity and aluminium toxicity in Latin American and some African soils affect the growth of sorghum. We have been able to develop cultivars (19) that are acid-tolerant and can produce better crops than the local varieties in this region.

18

19

Drought is a universal problem throughout the SAT. Some genotypes are more affected than others (20a). We use various techniques to screen material under controlled conditions, e.g., in this rainout shelter (20b) and under line-source irrigation (20c) at 1CRISAT Center. We are also studying the physiology of the plants to determine the mechanisms involved in drought tolerance or resistance. The results of these efforts culminate in the development of cultivars that can withstand drought like pearl millet ICTP 8203 that has been released as Okashana 1 in Namibia (21) and is doing well in farmers' drought-prone fields.

21

20a

20b

20c

22

23a

Biotic stresses are many and varied; they involve insect pests, pathogens, and weeds. Techniques that overcome several constraints at one time are available, e.g., soil solarization that involves covering the soil surface with polythene sheets (22, inset). The resulting increased temperatures under the cover reduce populations of soilborne nematodes, fungi, and insects. Crops grown in solarized soil (22, left) thrive better than those in nonsolarized soil (22, right).

A problem that affects many cereal crops is that caused by the parasitic weed *Striga* which parasitizes crop plants' roots depriving them of water and nutrients. A heavy attack combined with early drought can devastate a sorghum crop (23a). The annual losses to sorghum worldwide from this problem are estimated at U.S.$ 764 million. A genotype (SRN 39) originally from Nigeria, that was sent to Sudan in an ICRISAT screening nursery proved to be resistant to *Striga* under Sudanese conditions. It was used to develop a resistant variety released as Mugawin Buda 1 by the Sudanese national program, and is now being multiplied to provide seed for farmers (23b).

23b

24

25

26

27

Downy mildew is a crippling disease of pearl millet (24, inset) but luckily some genotypes have resistance (24, left). Using these and screening techniques (25) that use seedlings and produce results more rapidly in the laboratory than in the field ICRISAT developed WC-C75 (26) from a composite that originally came to ICRISAT Center from Nigeria. This variety was released by India in 1982 and by Zambia in 1987 as ZBMV 871. Private and public sector seed companies are now marketing WC-C75 very successfully (27) and farmers benefit from increased yields. Our linkages with the private and public sectors are essential for the transfer of technology to farmers; because it is the seed companies who use our material and produce seed in large amounts for sale to farmers. Recently an easily produced topcross hybrid of pearl millet, ICMH 88088 that resists both downy mildew and drought and is a very stable performer, has been developed by our breeders - evidence that we are continuing to stay ahead of the downy mildew pathogen.

Groundnut rust is endemic in most of the world's groundnut-producing countries. Techniques have been developed (28, inset) that enable us to work on the pathogen and the plants' mechanisms of resistance to it. These Jed to the release by India of rust-resistant 1CGS 44 now being grown by farmers in Karnataka (28).

Groundnut rosette virus (29) is transmitted by aphids. It causes severe losses to crops across the African continent, but does not occur in Asia. Wild *Arachis* germ plasm collected in South America was used to produce interspecific hybrids using cytogenetic and tissue-culture techniques at ICRISAT Center (30). When over 1000 genotypes were screened at the SADCC/ICRISAT Groundnut Project based at Chitedze Research Station near Lilongwe, Malawi, one of these interspecific hybrids showed resistance (31). It will be used in breeding programs to transfer the resistance to genotypes with other good traits.

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ICRISAT and our sister institute the International Center for Agricultural Research in the Drv Areas work together on kabuli chickpea and have developed ILC 3279 (32, right) that is cold-tolerant and resists ascochyta blight (32, left). The variety was released by Cyprus in 19S4, and later by Syria, Tunisia, and Iraq. The development of cold-tolerant lines makes it possible to sow chickpea during winter in the Mediterranean region instead of in the spring; yields from winter-sown crops are much higher than those from spring-sown crops. Chickpea can also be killed by fusarium wilt. After screening genotypes in wilt-sick plots (33, left), ICRISAT developed ICCV 2, the shortest-duration chickpea and first wilt-resistant kabuli for lower altitudes (33, right). It was released in Andhra Pradesh as Swelha in 1989.

The *Fusarium* fungus also attacks pigeonpea (34, left)-but we now have genotypes like ICPL 87119 (34, right) that resist both wilt and sterility mosaic disease.


35

Sorghum midge (35, left) attacks developing grain, resulting in chaffy florets (35, center) which do not fill or mature (35, right). ICSV 745 (36) has resistance and was released in 1989 by the Karnataka State Department of Agriculture for cultivation in midge-endemic areas where farmers appreciate the opportunities it affords to produce midge-free crops.

Some problems are yet to be fully solved. *Helicoverpa arniigera* (37, inset) has been studied by our entomologists for many years. Its larvae damage both pigeonpea and chickpea by boring into their pods. Pheromone traps (38) monitor adult populations in a network that spans south Asia and are used as a component of integrated pest management programs. Meanwhile, our breeders have developed pigeonpea ICPL 332 (37), that has good resistance to the caterpillars and was released in 1989 in Andhra Pradesh, an area where *Helicoverpa* damages both pulses and cotton causing severe economic losses.


36


39a

No change in technology or institution should be suggested unless the traditional system used by farmers is fully understood. From the time the Institute started work until the present, our economists have spent many months talking with farmers in the villages of India: Maharashtra, 1977 (39aj and 1985 (39b), Rajasthan 1990 (39c); and Africa, Burkina Faso 1980 (39d), and Niger 1982 (39e).

Major areas of impact of economics research at ICRISAT include production relations, nutritional status, risk, poverty, and common property resources. Such research has led to a greater conceptual understanding of agricultural development in the SAT, has influenced technology design, and has been an input into policy formulation in multilateral lending agencies, such as the World Bank. Much of this research is based on village-level studies (VLS) which have continued to bear fruit several years after the data were collected.


39b


39c


39d


39e

40

41a

41b

Collection of household records (40) from benchmark sites has provided a cost-effective vehicle for marshalling analytical talent in mentor institutes to address a range of developmental issues in the SAT of India and West Africa. More than 25 Ph.D. theses have been based on our source material.

Economics research questioned the relative priority which ought to be accorded to breeding for improved protein content and quality, versus improved yield and stability. This involved nutrition studies in the VLS which showed protein deficiencies were not so important as energy, vitamin, and mineral deficiencies (41a,b). More recent economics rescarch shows that income growth does *not* result in substantially enhanced nutritional status. These findings imply that breeders should comply with the poor's preference for higher quality food attributes, as well as selecting for higher-yielding cultivars, to ensure that their products would be eaten by the poor (42).

Analysis of the VLS data also shows that improved yield stability does not appreciably lessen instability in household incomes. Subsequent studies on drought have shown that households in poorly endowed SAT environments can effectively adjust to such risks. Agricultural researchers should therefore focus attention on increasing long-term productivity in preference to attempts to decrease variability.

42

Our research on trends in the size, productivity, and use of common property resources was the first of its kind in India (43). It has had a catalytic effect in focusing attention on pressing researchable problems in the SAT and has stimulated other researchers to carry out similar studies. Techniques for analyzing climatic data developed at ICRISAT have been used to guide the testing of appropriate germplasm in different agroclimatic zones. Appropriate emphasis can be given to the length of the growing season, exposure to drought at different stages of crop development, and selection for biotic stresses. This work, which began in India, has been extended to Africa and Asia. Agroclimatic research is now considered an essential ingredient in any dryland resource management program.

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4 b

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An essential part of our approach is the cooperation generated in the field between farmers and scientists. For example, the joint surveys to identify insect pests (44) conducted through the Asian Grain Legumes Network in Thailand in 1987, and the joint working group on peanut stripe virus that met in Indonesia (45) and involved the Peanut Collaborative Research Support Program, the Australian Centre for International Agricultural Research, ICRISAT, and the NARSs of China and Indonesia.

Identified problems find a range of solutions, e.g., the lack of fodder for farm animals in southern Africa can be alleviated by growing a pearl millet/napier grass hybrid developed at SADCC/ICR1SAT SMIP. The interspecific hybrid is finding acceptance among the farmers of the SADCC region. Sorghum flour can be made into both cookies and traditional *chapathis* to extend its use as a convenience food for city dwellers (46), and its stems can be used to make particle board for use in construction industries in areas where wood is scarce. Pigeonpea is very versatile, it can be used as a substitute for mung bean to make noodles that are a popular food in southeast Asian countries (47). When used as a component of agroforestry systems (48), its stems provide up to 4 t of fuel wood per hectare-very valuable for cooking in the fuel-scarce SAT (49). Groundnut, a vital source of protein and oil has long been eaten as a traditional snack food (50) but now it can be processed and preserved in many ways. Growing confectioner}' groundnuts offers the chance to augment incomes via the export markets to a wide range of countries who formerly only grew groundnut for their home markets (51).

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***ICRISAT assists in the development and transfer of technology to the farmer through cooperation with national and regional research programs, and by sponsoring workshop and conferences, operating training programs, and assisting extension activities.***

ICRISAT does not release the varieties, hybrids, breeding material it develops directly to farmers. They are shared with NARS scientists and tested on research stations and in farmers' fields by national programs throughout the SAT. If they do well, they are approved for release by the national programs. Over the years we have made many such contributions. Only a few are mentioned here: sorghum variety SPV 351 with resistance to several leaf diseases released as CSV 11 by India in 1984; and sorghum hybrid SPH 221 released by India in 1986 as CSH 11 (52). The first groundnut to be released by India was ICGS 11 in 1986, since then many others have followed, including BARD 699, a composite variety derived from ICRISAT selections that was released by Pakistan in 1989 (53). Chickpea Shwve Kyay Mon was released by Myanmar in 1986 (54a), Mariye by Ethiopia in 1988 (54b), and Nabin by Bangladesh in 1987 (54c). ICPL 87 a short-duration pigeonpea was released as Pragati by India in 1986 (55); and ICPH 8 the world's first pigeonpea hybrid released by India in 1991. It is now in commercial seed production at Nandikottur in Andhra Pradesh (56).

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54a

54b

54c

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- *Over 24 kabuli ICRISAT/ICARDA chickpea cultivars had been released under 41 names in 16 countries, and at least 17 desi and kabuli chickpea cultivars from ICRISAT Center in 6 countries by 1991.*
- *A third of the pearl millet crop groion in India is derived from improved genotypes developed at ICRISAT.*
- *Over 40 ICRISAT sorghum genotypes are growing in farmers' fields in the Americas, Africa, and Asia.*
- *The world's first pigeonpea hybrid to reach farmers' fields was ICRISAT's ICPH 8.*
- *Over 20 ICRISAT groundnut genotypes arc being grown by farmers in the Americas, Africa, and Asia.*

Farmers are the key to our success - we go to their fields (57) and they in turn come to ours at all our locations; e.g., ICRISAT Center 1979 (58). The feedback we receive from them is vital to our research.

National program scientists also visit us, e.g., the Nigerians who visited our WASIP—Nigeria trials; the twenty-five scientists from 11 countries and 7 international organizations who met in 1978 to discuss the Agroclimatological Research Needs of the Semi-Arid Tropics; and the 54 delegates from 13 countries who came to ICRISAT Center in 1979 for an International Workshop on Socio-economic Constraints to Development of Semi-Arid Tropical Agriculture (59).

Regional meetings such as the one for grain legumes in eastern Africa held in Ethiopia in 1986 (60) can be very effective; that meeting resulted in collaborative work on pigeonpea starting in the region, and by 1991 we had established trials and locally adapted material growing in Kenya.

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Our workshops range from country-specific, e.g., Phosphorus in Indian Vertisols (61), to the Regional Groundnut Workshop for Southern Africa, held in 1988 in Lilongwe, Malawi, and the International Workshop on Farming Systems that ICRISAT hosted in 1986 tor all the CGIAR Centers.

60


61

National systems and research institutions are only as good as their staff can make them. Human resource development is essential if the research capabilities of national programs are to be developed. ICRISAT Center has over the years provided learning opportunities to over 2234 trainees from 89 countries.

Research scientists and technicians spend varying lengths of time with us. They conduct research, work in experimental fields (62a) and laboratories (62b), and assist our scientists in VLS (62c). At all our locations opportunities to learn and participate in our projects are provided to students at all levels, and to national scientists who come to share their knowledge and experience with us. Some of these are involved with special projects, e.g., the Government of Japan work on phosphorus nutrition of grain legumes (63). ICRISAT provides facilities for students studying for higher degrees to do their project work, and also assists NARS scientists to study for higher degrees, e.g., the SADCC/ICRISAT SMIP assists scientists from the SADCC region to study for higher degrees in USA, Canada, and Brazil.

62a

62b

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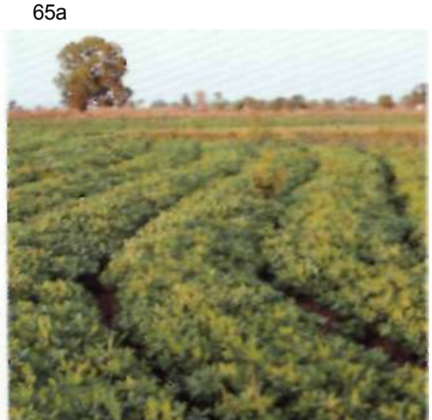
62c

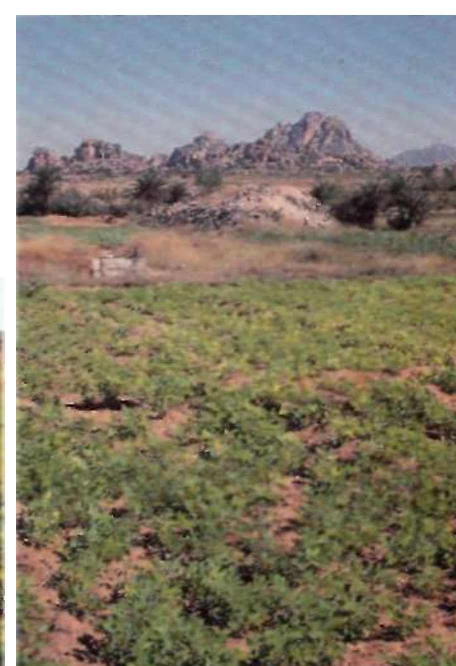
Our material and technologies also reach farmers through international extension efforts such as those made by Sasakawa Global 2000 in Tanzania (64) in collaboration with our Eastern Africa Regional Cereals and Legumes program.

Some efforts are special. In 1987, ICRISAT was requested by the Government of India to help extend its groundnut varieties and production technologies to farmers in India in an attempt to increase oilseed production. The efforts over several years by the Legumes On-Farm Testing and Nursery Unit working through 141 on-farm trials in eight states produced quite dramatic improvements in groundnut yields (65a) compared with the local system (65b).

64

65a





65b

66

67


68a

68b

Our Library (66) provides a comprehensive background to our scientists' \vork,it has access to the latest on-line information from several of the world's premier agricultural databases and it provides support to over 370 scientists in the NARSs (67) through the Semi-Arid Tropical Crops Information Service. This service means that scientists isolated from libraries can still keep abreast of their peers by having the latest published material on their research topics provided free to them at regular intervals.

We reach the public through a range of media; by our publications, by those of our scientists in the world scientific literature, and by press releases and magazine stories (68a, b, c). We also encourage our scientists to broadcast on radio (69a, b) and television (69c) to reach the widest possible audiences.

69a

69b

69c

ICRISAT also tries to help the community in which it works. 1CRISAT Ladies Association for the Welfare of Women and Children founded in 1980 at 1CR1SAT Center, organizes self-help programs (70a), and supports education (70b) and health programs (70c) for ICRISAT employees and their children.

70a

70b

70c

# ICRISAT—The Years Ahead

Nearly one-third of the 800 million inhabitants of the SAT live in poverty. That fact, together with the periodic recurrence of drought and famine, guarantee the region's high priority on the list of donor concerns.

ICRISAT's mandate crops continue to be the important food crops of the SAT. Our scientists are dedicated to the continued development of improved cultivars and breeding lines to meet the food needs of the ever-increasing population. Germplasm enhancement, and concentration on combating globally and regionally important yield-reducing stresses will continue to be our main areas of emphasis.

Within the fragile environment of the SAT, it is vital that the resource base on which crops are produced is not damaged in the push for higher yields. ICRISAT is very conscious of the need to maintain such sustainability, and is working on the development of farming systems that make more efficient use of low inputs. These new systems aim to provide for the timely application of water while enriching nutrient-poor soils and preventing erosion from runoff in the unpredictable, intensive rainstorms common to much of the SAT.

Women will continue to play a vital role in agricultural development in the SAT as farmers, field workers, homemakers, and increasingly, as research technicians and scientists. We are aware of the considerable barriers to full participation which women still face in many countries and we encourage the removal of those obstacles.

We will look for new skills in social sciences to support the shift towards research on institutional constraints, gender issues, and evaluation of research achievements. Constant or declining budgets increase the demand for formal modeling and other analytical techniques when allocating resources for research.

We will continue to assess the usefulness of new technologies to increase the efficiency of our research. Biotechnology, for instance, will become increasingly useful in our crop improvement research.

Assessing the reasons for a project's success or failure is essential when planning future research projects. Because we must become even more cost-effective and accountable, we will conduct impact assessment studies in full cooperation with scientists in NARSs.

We have developed, but must improve upon, methods for determining priorities in strategic resource management research. Particular emphasis will be placed on the importance of quantification, and will include the development of long-term experiments involving both cereals and legumes.

We believe we work well with national programs, but we must reach out farther to establish working partnerships that are appropriate to what is possible and to our partners' resources, priorities, and national policies. Even though ICRISAT programs have trained more than 2000 scientists and technicians to help improve food production in many countries, some national programs are still unable to maintain effective research programs. We will work for better coordination of training programs across centers and with the stronger national programs. We will encourage stronger NARSs to provide leadership in collaborative research networks and we shall continue to support [he NARSs in smaller countries. We shall maintain and strengthen our information management and exchange services and capabilities.

ICRISAT is an effective research and training institute of scientific excellence and with measurable impact. We have worked hard to make it so. We hope to receive the support and contributions necessary to achieve our plans, with the CGIAR coordinating support for most of our core activities.

The role ICRISAT will retain, despite dynamic change in its programs and projects, is that of a provider of new scientific methodology and improved germplasm of its mandate crops, and as a coordinator of scientific and information exchange. We expect to continue to be a vital contributor to agricultural development well into the 21st century. These strategies will enable ICRISAT to fulfill its global mandate and to maintain its reputation as a center of excellence.

# Milestones

1972 - Memorandum of Understanding for the formation of ICRISAT signed between the Government of India and the Consultative Group on International Agricultural Research (CGIAR) on 28 March
- City office opened 1 April in what is now ICRISAT Guest House
- Property title tor ICRISAT Center transferred 27 April.
- First international staff appointed
- First experimental trials sown, 24 June.

1973 - First Indian national scientists appointed

1974 - First group of In-Service Trainees arrived.
- Laboratories established in Banjara Hills, Hyderabad.
- First international workshop on Farming Systems held, 18-21 November

1975 - Hon. Mrs Indira Gandhi, Prime Minister of India laid the Foundation Stone, ICRISAT Center, 11 January
- Village level studies initiated in India, May.
- Regional cooperative program for West Africa launched; work started in Upper Volta (now Burkina Faso)

1976 - Establishment of ICRISAT West Africa Sorghum and Pearl Millet Improvement Project, based at Dakar, Senegal.
- Groundnut added as the fifth mandate crop.
- Dedication of Lake ICRISAT, April
- Visit of R.F. McNamara, President of the World Bank, November.

1977 - Decision to include minor millets in germplasm collections, March.

1978 - Establishment of Core Program in Africa.
- First Quinquennial Review.
- Establishment of Export Certification Plant Quarantine Laboratory at ICRISAT Center.
- Initiation of cooperative research project with All India Coordinated Research Project for Dryland Agriculture (AICRPDA) on watershed development and management.

1979 - Inauguration of new facilities at ICRISAT Center, by Hon. Charan Singh, Prime Minister, India, 30 August
- Establishment of Genetic Resources Unit.

1980 - Establishment of Electron Microscopy Unit.

1981 - Memorandum of Understanding signed with Government of Niger for the establishment of ICRISAT Sahelian Center (ISC) at Niamey.
- ISC became operational.
- Governing Board Meeting held at Ouagadougou, Burkina Faso.
- First release of an ICRISAT crop variety, pearl millet Ugandi (Sudan).

Sowing the first trials, ICRISAT Cento; 1972.

R.F. McNamara, President, World Bank, with Associate Director, J,S. Kanwar, during a visit to Manmool village on ICRISAT Campus, November 1976.

The first trainees from Nigeria at ICRISAT with A.S. Murthy, E.G. Lawrence, M. and R.VV. Cummings, and J.S. Kanwar, 1974.

R.VV. Cummings performing the ground-breaking ceremony to start construction of ICRISAT Center, 1975.

The first workshop. Ritz Hotel, Hyderabad, 1974.

Laying the Foundation Stone for ICRISAT Center, 11 January 1975. Her Excellency Hon. Mrs Indira Gandhi, Prime Minister of India, and J. Vengal Rao, Hon. Chief Minister of Andhra Pradesh.

1982 - ICRISAT celebrated its 10th anniversary.
- Release of four sorghum varieties (People's Republic of China), hybrid Hageen Durra 1 (Sudan); and pearl millet WC-C75 (India).
- Establishment of SADCC/ICRISAT Groundnut Project, Lilongwe, Malawi.
- Establishment of Comision Latinoamericano de Invcstigadores en Sorgo (CLAIS).

1983 - Illa Maikassoua, Hon. Nigerien Minister for Higher Education and Research, laid the Foundation Stone of ISC, 16 August.
- H.M. Queen Elizabeth II and H.R.H. Prince Philip, Duke of Edinburgh, visited ICRISAT Center, 19 November
- Release of sorghums ZSV 1 (Zambia), ISIAP Dorado, and San Miguel 1 (El Salvador); chickpea ICCV 1 (India); and pigeonpea QPL 1 (Australia).

1984 - Establishment of SADCC/ICRISAT Sorghum and Millets Improvement Program (SMIP).
- SAFGRAD/ICRISAT Regional Sorghum and Millet Project for Eastern and Southern Africa, started at Katumani, Kenya.
- Release of sorghums ICSV 1 (CSV 11) (India), ESIP 11 (IS 9302), and ESIP 12 (IS 9323) (Ethiopia); chickpea ILC 3279 (Yialousa) (Cyprus).

1985 - Construction of SMIP office and laboratory buildings at Matopos, Zimbabwe started.
- Release of sorghum hybrid ICSH 1 (India), ICSV 112 as SV1 (Zimbabwe), ICTA Mitlan 85 (Gautamela), M 62650 as Sureho (Honduras), Nica-sor (T-43) (Nicaragua); pearl millet varieties, ICMV 4 as ICMS 7703 (India), ICMV 5 as ITMV 8001, ICMV 6 as ITMV 8002, ICMV 7 as ITMV 8304 (Niger); chickpeas ICCC 32 (ICCV 6) (India), ICRISAT/ICARDA cultivars ILC 720 as Fardan, ILC 200 as Zegri, ILC 254 as Almena, ILC 2555 as Alcazaba (Spain); pigeonpeas ICP 7035 as Kamika (Fiji), Quantum (Australia).

Celebrating 10 years of ICRISAT, 1982.

Hon. Minister for Higher Education and Research, Niger, and J.L. Dillon, Chairman, ICRISAT Governing Board (November 1983-March 1986) laying the Foundation Stone for the ICRISAT Sahelian Center, Sadore, 16 August 1983.

Her Majesty Queen Elizabeth II with L.D. Swindale. Director General ICRISAT (1977-1991), during her visit to ICRISAT Center, November 1983.

President Seyni Kountche of Niger (extreme right) in discussion with ICRISAT scientists R.W. Gibbons, Executive Director, ISC (Centre) and C. Renard, Team Leader, Resource Management Program, (2nd from right) during his visit to ISC, 2 October 1986.

C.L. Paul (LASIP) and L.D. Swindale with award presented to ICRISAT by Agroconsultures, S.A. de C.V., for help in the development of Agroconsa I, 1988.

F.V. McHardy, Chairman, ICRISAT Governing Board (April 1986-March 1989), at the inauguration of ICRISAT Sahelian Center, 7 March 1989.

Field day to commemorate inauguration of EARCAL facilities at Kiboko, Kenya

1986 - First meeting of Governing Board in Zimbabwe, 14-18 Mar.
- ICRISAT Management reorganization.
- Memoranda of Understanding signed with Bangladesh and Burma (now Myanmar).
- Establishment of Asian Grain Legumes Network (AGLN), Eastern Africa Regional Sorghum and Millets Network (EARSAM), West and Central African Sorghum Research Network (WCASRN).
- Hon. Sevni Kountche, President of Niger visited ISC 2 Oct.
- Release of sorghum hybrid CSH 11; three pearl millet hybrids ICMH 451 (MH 179), ICMH 501 (MH 180), and ICMH 423 (MH 143) (India); chickpea cultivars Shwye Kyay Mon (Mvanmar) ILC 482 as Ghab 1, ILC 3279 as Gh'ab 2 (Syria), ILC 3279 as Chetoui, FLIP83-46C as Kassab, Be-sel-81-48 as Amdoun 1 (Tunisia); ILC 195, and ILC 482 as Gun Cy Sarisi 482 (Turkey); pigeonpea varieties ICPL 87 as Pragathi, and TCPV 1 as Maruthi (India); **and** groundnut variety 1CGS 11 (India).

1987 - Memoranda of Understanding signed with Nepal, Nigeria, and Sri Lanka.
- Establishment of Legumes On-Farm Testing and Nursery Unit (LEGOFTEN).
- Release of sorghum varieties Blanco 86, UANL-1-187, UNAL-1-287 (Mexico); pearl millet variety WC-C75 as ZPMV 871 (Zambia); chickpea ICCL 81248 as Nabin (Bangladesh), ICCV 1 (ICCC 4) as Sita (Nepal); ILC 464 as Kvrenia (Cyprus); ILC 172 as Califfo, ILC 3279 as Sultano (Italy), ILC 195 and ILC 482 (Morocco), ILC 1335 as Shendi (Sudan); and pigeonpea variety Megha (Indonesia).

1988 - Establishment of Cooperative Cereals Research Network (CCRN).
- Operations in Burkina Faso terminated.
- Memorandum of Understanding signed with Peoples' Republic of China.
- Release of sorghums ICSV 112 (CSV 13), SAR 1 (ICSV 145); pearl millets MP 124 (ICTP 8203), ICMA 841 and ICMB 841 (India); INIAP 201 (Ecuador), Agroconsa I (El Salvador); chickpeas ILC 482, ILC 3279 (Algeria), ILC 202 and ILC 411 (China), ILC 482 (TS 1009) and FLIP 81-293C (TS 1502) (France), ILC 237 (Oman), JG 74 as Radha (Nepal), Mariye (Ethiopia); pigeonpeas Quest (Australia), ICP 9145 as Nandolo Wansawara (Malawi); and groundnut ICGV 87128 (ICGS 44) (India).

1989 - Inauguration of ISC, Niamey, 7 March and Governing Board Meeting at ISC, 5-7 March.
- Foundation Stone laid for ICRISAT regional research complex for sorghum improvement in West Africa by Hon. Cheik Bougadary Bathily, Cabinet Director of the Malian Ministry of Agriculture, Samanko, Mali, 11 August.
- Memorandum of Understanding signed with Vietnam.
- Release of sorghum varieties ICSV 112 as SV 1 (Zimbabwe), M 62641 as Costeho 201 (Mexico), SDS 3220 as Macia, and IS 8571 as Mamouhe (Mozambique), WSV 387 as Kuyuma, WSV 187 (IE 2929) as Sima (Zambia), sorghum hybrids MMSH 413 and MMSH 375 (Zambia), SPV 351 (Malawi); germplasm lines IS 2391 as SDS 1513, and IS 3693 as SDS 1594-1 (Swaziland); pearl millets ICTP 8203 as Okashana 1 (Namibia), ICMV 82132 as Kaufela (Zambia); finger millets IE 2929 (Zambia); chickpeas ICCV 2 as Swetha, and ICCC 37 as Kranthi, (India), ILC 482 as Janta 2 (Lebanon), ILC 5566 as Elmo and FLIP 85-17C as Elvar (Portugal); pigeonpea selection ICPL 322 as Abhaya, and ICPL 151 as Jagriti (India); and groundnuts ICGV 87141 (ICGS 76), (India), and BARD 699 (Pakistan).

1990 - Inauguration of EARCAL program facilities at Kiboko Research Station, Kenya Agricultural Research Institute (KARI), 25 June.

- Establishment of West and Central African Millet Research Network (VVCAMRN).
- Release of sorghum varieties Pacifico 301 (Mexico), Pinolero 1 (Nicaragua), germplasm selection E 1966 as NTJ-2 (India); chickpea varieties ICCV 6 as Kosheli, and ICCV 82108 as Kalika (Nepal), ILC 482 as Jubeiha 2 and ILC 3279 as Jubeiha 3 (Jordan); FLIP 85-7 as Damla 89, FLIP 85-135C as Tasova 89 (Turkey) pigeonpea variety ICPL 87 (Mvanmar); groundnut varieties ICGS 37, ICG(FDRS) 10, ICGS1, ICGS 5, (India), germplasm line ICG 7794 (Ethiopia), ICGMS 42 (Malawi)

1991 - Release of world's first pigeonpea hybrid ICPH 8 (India).
- Inauguration of West Africa Sorghum Improvement Program (WASIP) building complex, Samanko, Mali, by Hon. Moulaye Haidara, Malian Minister of Agriculture, 14 February.
- The 2000th participant in ICRISAT Center Human Resources Development Programs arrived, 1 April.
- Memorandum of Understanding signed with USSR, April.
- L.D. Swindale honored with Padma Bhushan by H.E. R. Venkataraman, President of India; and with a golden *Ciwara* (Great Cultivator), by the agricultural researchers of Mali.
- Preparation of *Pathways to Progress*—ICRISAT's Strategic Plan for the Nineties.
- Establishment of monoclonal antibodies laboratory at ICRISAT Center funded by Asian Developement Bank (AsDB).
- Establishment of insecticide-resistance testing laboratory at ICRISAT Center in collaboration with Natural Resources Institute (NRI), UK.
- Development of Vertisol watersheds collaborative project with International Livestock Centre for Africa (ILCA) and Institute of Agricultural Research (IAR) in Ethiopia.
- Malian Government and USAID express gratitude for ICRISAT's contribution to Malian agriculture, upon termination of ICRISAT/Mali Bilateral Program, May.
- Release of Striga-resistant sorghum varieties Mugawim Buda 1 and Mugawim Buda 2 (Sudan), M 90812 as Tropical 401, and PP 290 as Perlita (Mexico); pearl millet variety IKMV 8201 (Burkina Faso), ICMV 155 (India); chickpea lines FLIP 82-105C as Ghab 3 (Syria), 87 AK 71115 as Akcin (Turkey), FLIP 84-79C and FLIP 84-92C (Algeria and Tunisia), FLIP 84-92C (Morocco), ILC 3279 and ILC 482 (Iraq); pigeonpea ICPL 84045 (Sri Lanka); groundnut varieties ICGV 86590 with multiple-diseases and insect-pests resistance, and ICGS 1 selection Konkan Gaurav (India), ICGS 114 as Sinkarazei (Ghana).
- Long-term genebank inaugurated, ICRISAT Center, 10 Maw

1992 - V. Rajagopalan, Chairman, CGIAR, visited ICRISAT Center, 7 February.
- Pigeonpea varieties ICP 11384 released as Bageswari, and Rampur Local as Rampur arhar (Nepal), ICPL 87119 (India).
- Establishment of Cereals and Legumes Asia Network (CLAN).

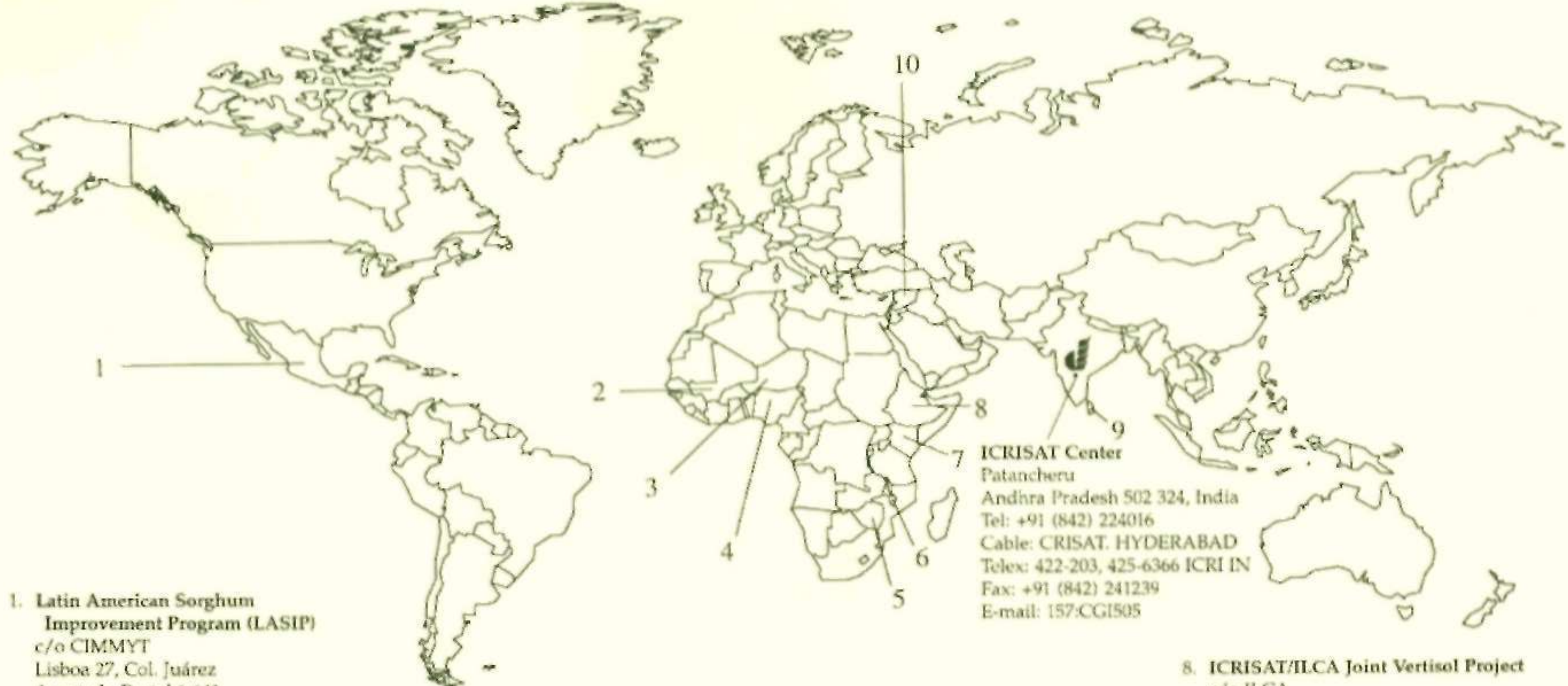
L.D. Swindale receiving the Padma Bushan award from His Excellency R. Venkataraman, President of India, 23 March 1991.

Hon. Moulaye Haidara, Minister of Agriculture, Mali (center) during his visit to inaugurate WASIP buildings, Samanko, 14 February 1971. Extreme left, S.N. Lohani, Team Leader, WASIP-Mali.

J.G. Ryan accepting the Director Generalship of ICRISAT from W.T. Mashler, Chairman. ICRISAT Governing Board (April 1989-March 1992). 19 August 1991. (Center Y.L. Nene, Deputy Director General.)

E.H. Roberts, Chairman, ICRISAT Governing Board, (from April 1992) and L.R. House, Executive Director, Southern African Programs, during Governing Board meetings in SADCC, March 1991.

V. Rajagopalan, Chairman, CGIAR during his visit to ICRISAT Center, 1992, with J.G. Ryan, and S.B. Sharma, Nematologist.

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