# ICRISAT in Africa

***Cover:*** *Two faces of the Sahel: the general environment, desert-like and hostile to crop production; and a happy farmer (inset) in Gaya village, Niger, with his millet harvest, aided by research.*

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**ICRISAT**

**International Crops Research Institute for the Semi-Arid Tropics**

**Patancheru, Andhra Pradesh 502 324, India**

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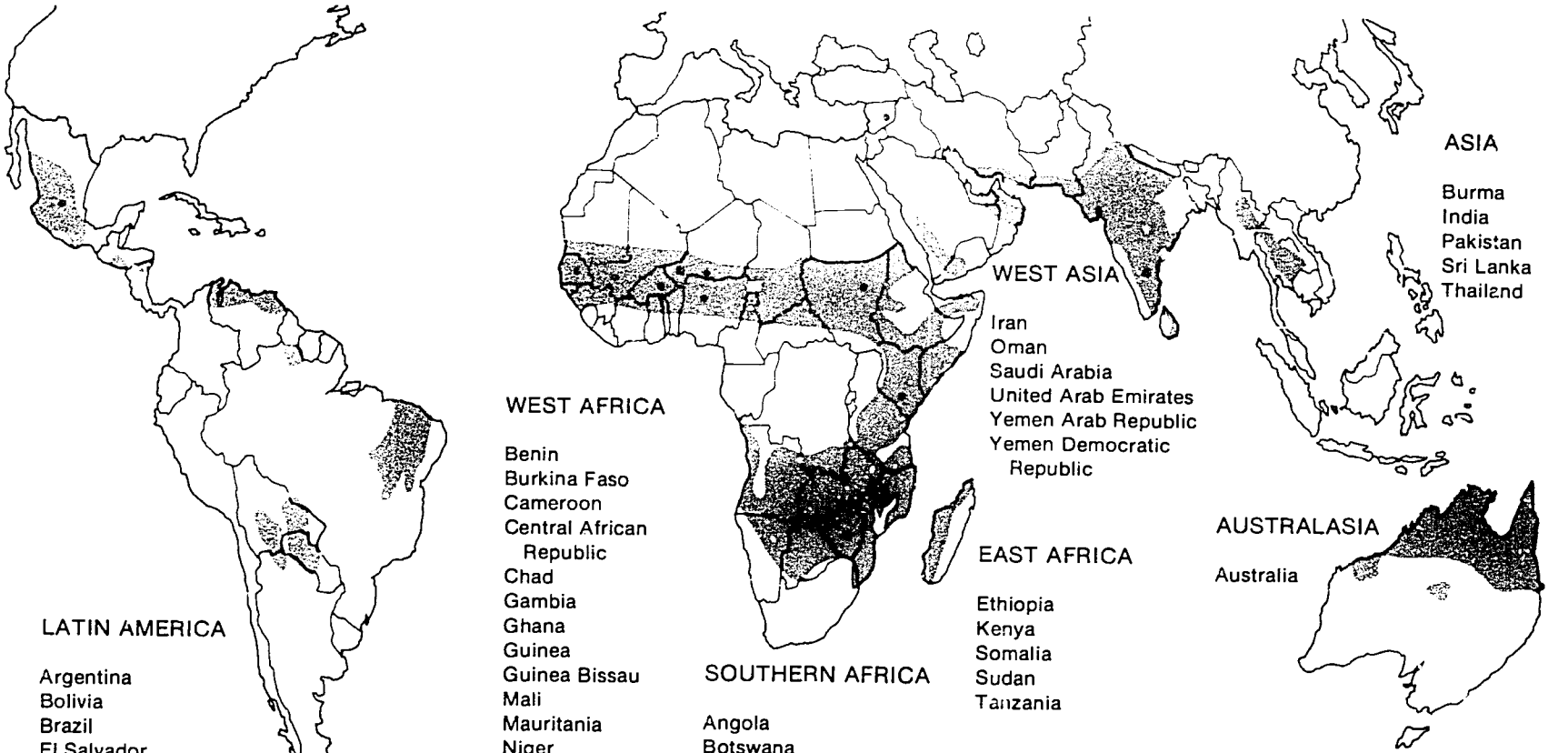



*Semi-arid areas (in yellow) covered by ICRISAT's mandate. Green squares indicate location of ICRISAT Center in India and Sahelian Center in Niger; red dots indicate collaborative research stations where ICRISAT scientists have been posted.*

# About ICRISAT

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

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

The SAT is a harsh region of limited, erratic rainfall and nutrient-poor soils. It is populated by more than 700 million people, most of whom live at subsistence levels and depend for their food on the limited production of small farms.

The crops researched by ICRISAT are sorghum and pearl millet—two of the major cereals in the SAT—and chickpea, pigeonpea, and groundnut, the most important food legumes of the region. Groundnut, rich in oil, is also an important cash crop for the SAT farmer. The four others are all primarily subsistence food crops; over half the total production of each—in some places nearly all of it—is consumed on the farms where it is grown.

ICRISAT's headquarters are at Patancheru, India, 26 km northwest of Hyderabad, but it also has scientific staff posted in seven countries of Africa, in Mexico, Pakistan, and Syria, and at five cooperative research stations of agricultural universities in India. Principal operations in Africa are in Burkina Faso, Kenya, Malawi, Mali, Niger, Sudan, and Zimbabwe. Scientists were previously posted also in Nigeria and Senegal, but funding for these positions has ceased. The search is on for a suitable site to locate a West Africa regional program for sorghum. The two main bases for ICRISAT's future work in Africa, as currently envisaged, will be at the new Sahelian Center near Niamey, Niger, and the SADCC/ICRISAT sorghum and millets improvement program at Matapos, near Bulawayo, Zimbabwe, set up in response to an invitation from the nine-nation Southern African Development Coordination Conference (SADCC).

*Food production emergencies in Africa as classified by the UN Office of Emergency Operations in Africa, New York, USA. Localized drought is prevalent in several other countries. Dots/square show locations of ICRISAT research as indicated.*

# Introduction

Africa's continuing food crisis has captured headlines with accounts of famine and human misery. A compassionate world has responded with food aid to alleviate suffering.

But providing food for Africa's future is a long-term project, a matter of increasing productivity on exhausted land that cannot make efficient use of the rain that falls.

ICRISAT, the International Crops Research Institute for the Semi-Arid Tropics, is carrying out agricultural research to help Africa help itself avoid future food crises.

ICRISAT scientists are, or have been, posted in 10 African countries and also work with national scientists, agricultural institutes, and collaborating agencies in at least 23 others.

ICRISAT has developed improved varieties of sorghum and millet, two essential food crops of subsistence farmers in drought-prone areas, which are now grown on farmers' fields in Africa.

ICRISAT's studies in farming technologies are showing how farmers can increase production through more efficient use of available materials and better tillage methods.

ICRISAT is providing African national scientists with germplasm, training, and support that will help countries develop strong programs in sorghum, millet, and groundnut production.

ICRISAT believes its programs will help Africa reach its goal of providing adequate supplies of nutritious food for the future.

This booklet tells the story of ICRISAT's work in Africa.

**L.D. Swindale**
**Director General**

# Food for the Future

Twice in the past 15 years the world has been shocked by the vision of starving peoples in Africa, where devastating droughts have wiped out the crops of peasant farmers.

Billions of dollars have been raised for emergency food relief and medical care, but relatively little has been targeted for long-term research on how to increase and stabilize food production.

Weather conditions improved and food production increased in several countries late in 1985, but history shows that the problems of the subsistence farmer do not go away for long. There will be more droughts, more plagues of insects, more disease-ravaged fields. Rapid population growth means more and more mouths to feed; food supplies that are adequate this year won't satisfy the demand next year or the year after.

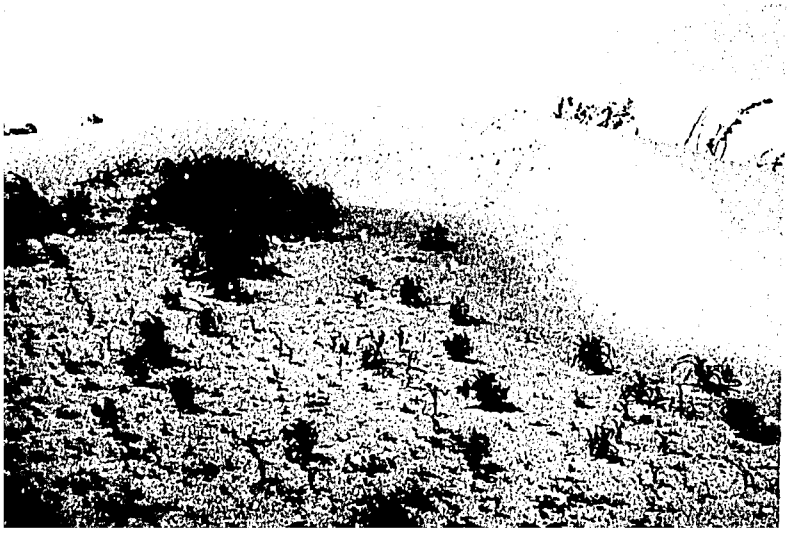
Complacency or overoptimism could lead to another desperate emergency in the future. But vigorous research action now to develop improved, high-yielding, disease-resistant food crops can mean a healthier, happier future for the long-suffering people of semi-arid regions in Africa.

In the past, research on subsistence food crops has not had a sufficiently high priority for African governments, which have emphasized industrial development, export crops, and foods preferred by city dwellers. Attempts at wholesale transfer of western technologies and improved seed varieties have been no more successful than development schemes that bypassed the peasant farmer in favor of highly mechanized food production. Strengthening national and regional research that will benefit the small-scale farmer must become the first priority in assuring sufficient food for the future.

## Natural and Manmade Problems

Though Africans are creative and resourceful in coping with a difficult environment, their crop yields per hectare are the lowest in the

*Throughout the Sahel, environmental conditions are extremely difficult for crop growth. Observe the millet plants (below, right) hit by sand blast.*



*Millet heads being threshed near a field granary, where they are stored after harvest.*

world. Three-quarters of the people of Africa are farmers, yet per capita food production dropped by 20% between 1960 and 1980, a period of rapid population growth.

Twenty-four African nations faced acute food emergencies early in 1985, and more than half the population lives in conditions of absolute poverty, below any level of human dignity.

Low and unpredictable rainfall, poor soils, extremely high soil surface temperatures, vicious winds, diseases and pest problems found nowhere else, and continuing soil degradation are natural problems that complicate attempts to improve agricultural productivity.

Government pricing policies that do not encourage production of food crops, provide for efficient seed production and distribution, or make chemical fertilizer available, are manmade hurdles. So is well-meant food aid that results in imported rice, maize, or wheat being sold at lower prices than locally produced sorghum and millet.

## Substantial Increases Possible

Money spent for agricultural research can lead to substantial increases in food production. ICRISAT, for example, is developing improved crop varieties and hybrids, as well

as technologies for their production, which will help bring this about in large areas of Africa.

ICRISAT, which has been doing agricultural research in Africa for more than 10 years, is one of 13 nonprofit research centers supported by the internationally funded Consultative Group on International Agricultural Research (CGIAR). ICRISAT's main center is at Patancheru, near Hyderabad, India, where it holds a world mandate for research on five crops: sorghum, pearl millet, groundnut, pigeonpea, and chickpea. A regional center to serve the Sahelian region of West Africa is being developed at Sadoré, near Niamey, Niger.

Sorghum and millet are staple foods throughout much of semi-arid Africa, groundnut is widely grown as a food and cash crop, and pigeonpea is being introduced in western Africa as a source of protein for people and a means of enriching soils through nitrogen fixation.

An ICRISAT hybrid sorghum developed in the Sudan with funding from the United Nations Development Programme (UNDP) was hailed by M. Peter McPherson, Administrator of the United States Agency for International Development (USAID), as "one of the first steps in the long and complex journey toward the goal of food self-reliance in Africa."

In addition, ICRISAT pearl millet varieties have been released or recommended for release in Senegal and Niger. Seeds from these varieties are being reproduced, and there will be large-scale demonstrations in farmers' fields in Chad, Mali, and Cameroon. Several varieties are in regional trials conducted by the Institut du Sahel (CILSS) in seven West African countries.

Two ICRISAT sorghum varieties are in use in Burkina Faso, sorghum introductions from ICRISAT Center have been released in Ethiopia, Zambia, and Zimbabwe, and Sudanese farmers are cultivating an ICRISAT-developed pearl millet. Two ICRISAT sorghum varieties have shown great promise in Zimbabwe and have been released there.

## Initial Strategies

Such successful adaptations, however, have

*Farmers such as these (below, facing page) are the ultimate target of ICRISAT's research. They use primitive tools (see* daba *at right below, used in sowing millet seeds), depend on the farm produce for sustenance, and are traditionally poor. ICRISAT's research aims to improve their lot.*

been rare in the history of attempts to boost food supplies on the African continent.

ICRISAT's experience in Africa, particularly with pearl millet, has shown that cultivars must be developed in the African environment to be well-adapted to it, and technologies must offer the likelihood of success in dry as well as wet years. Research must also aim at more efficient use of human and natural resources.

The Institute has found that research innovations currently available do not result in large enough improvements to persuade the farmers to make significant changes in their traditional farming practices. Much more than small changes at the margin are required.

Initial strategies cannot afford to be too complicated. They must be based more on yield stability and sustainability than on highest yields per hectare and must emphasize farmer-adapted means of improving and conserving soil water and soil fertility. The limited resources available should be applied only to input/crop/livestock combinations showing the greatest promise for the different climatic zones.

## Africa's Priceless Resource—Germplasm

Africa has useful raw material (germplasm) for increasing food crop production. Imaginative use of this priceless resource for selection and hybridization of suitable varieties is a central part of ICRISAT's agricultural research.

African farmers cultivate traditional landraces (locally selected varieties) that have the genetic traits that help them survive in a harsh biological and physical environment, but these landraces do not usually produce grain abundantly. Scientists' increasing knowledge and understanding of germplasm diversity makes it possible for them to select and combine genetic traits from these African cultivars with those from other parts of the world to develop varieties that are both high-yielding and adapted to external conditions.

As farmers have accepted developed varieties, however, primitive local strains with their valuable genetic properties have become increasingly rare and in some cases have virtually disappeared. ICRISAT Center's Genetic Resources Unit in India, the world repository for germplasm of its five mandate crops, has collected and stored seed (which carries the genetic material) of these endangered varieties.

It has been able to supply African researchers with thousands of selections from Africa and other areas in a continuing scientific exchange. This has been a beneficial tool, both for ICRISAT and for the national research programs that it works with throughout the semi-arid tropics.

## No Quick Solution

ICRISAT scientists recognize that using this genetic wealth, introducing new material, and developing cultivars adapted to the demanding African environment call for years of testing in the laboratory and in the field.

Improved cultivars are only one piece in the puzzle, and it is clear there will be no quick solution to Africa's food supply problems; in fact, the solution may be as much as 20 years down the road. New lands available for cultivation, for example, are only marginally suited to agriculture. But moderate increases in cropping intensity or land productivity are possible under existing conditions, particularly through adoption of more efficient cropping systems.

Conditions that made for the Green Revolution in Asia and Latin America cannot be found in Africa today, though fragments of the necessary technology are available. It took at least 20 years of painstaking scientific endeavor to develop "miracle" rice and wheat, with technologies that used plenty of fertilizer, irrigation, and herbicide and were financed with vast amounts of foreign aid.

National agricultural programs must be supported, strengthened, and expanded so that African scientists can become more active participants in solving their own development problems if there are to be any real breakthroughs.

## Policies Must Change

Most observers agree that government policies must change radically—and there are signs that they are changing—giving agriculture an increasing role in development strategies, coordinating research with farmers' needs, transferring domestic resources to modernization of small-holder agriculture, and focusing on a smaller number of important areas.

If the devastating events of recent droughts are not to be repeated again and again, an effective strategy must be developed and carried out. Soils must be rehabilitated and the advance of the desert halted and even reversed.

Some inputs must be obtained and made available to farmers, perhaps through grants in aid. It might be cheaper to import fertilizers than to import food grains, though eventually nations of Africa must exploit potential local sources of phosphorus and nitrogen.

Agricultural research achievements must be accompanied by extension activities, attractive and consistent prices, and improved road and rail links to remote villages so farmers can get seed, fertilizer, and other supplies, if food production is to increase significantly.

## Sharing Research Responsibilities

Though African governments are gradually making necessary changes in policy that will improve their agricultural research systems, the problems are too massive for them to tackle alone. Research responsibilities must be shared among national, regional, and international agencies.

ICRISAT's research is moving to the forefront in helping the nations of a hungry continent discover how they can provide food for the future and end the seemingly endless cycle of poverty and starvation that has haunted generations of African farmers.

The following pages describe some highlights of ICRISAT's many-faceted research in semi-arid Africa. Each program is different, and each seeks to meet a specific need.

# ICRISAT Sahelian Center

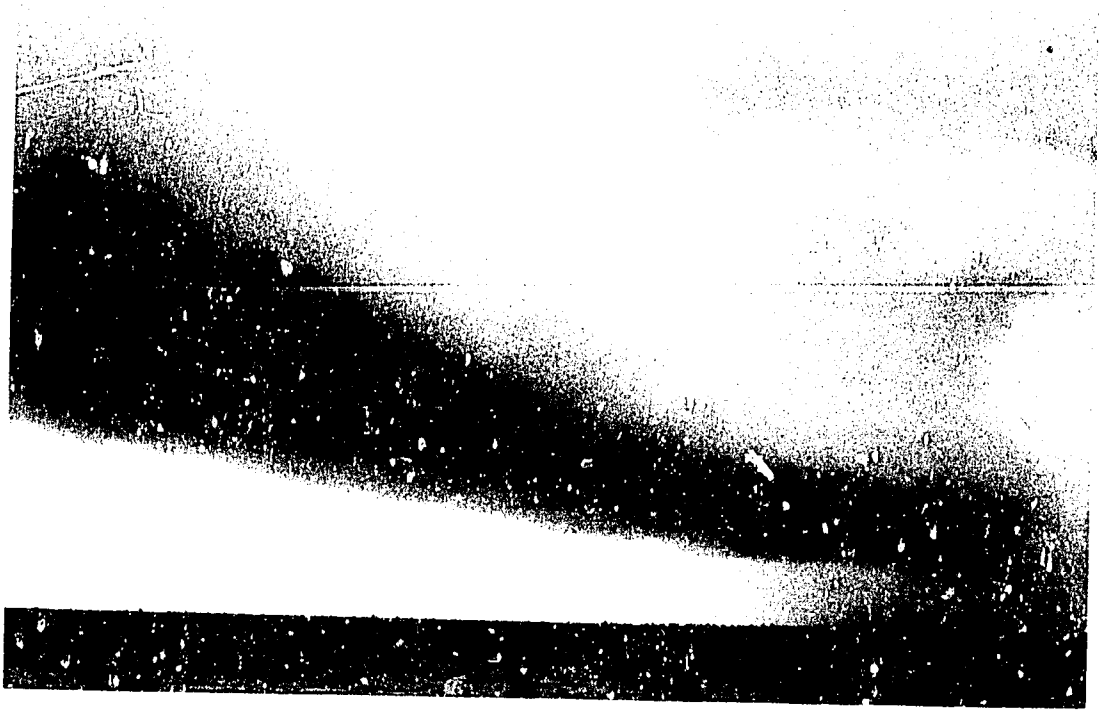
The Sahel has been the subject of countless newspaper and television reports, yet we know very little about it. Has weather really changed radically? Can food production be increased? Can the depleted soil be reclaimed?

The new ICRISAT Sahelian Center (ISC) at Sadoré, Niger, focuses on this wide "hunger belt" that includes Mauritania, Senegal, Mali, Burkina Faso, Niger, Chad, Gambia, Cape Verde, and parts of the Ivory Coast, Ghana, Togo, Benin, Nigeria, Cameroon, and the Central African Republic.

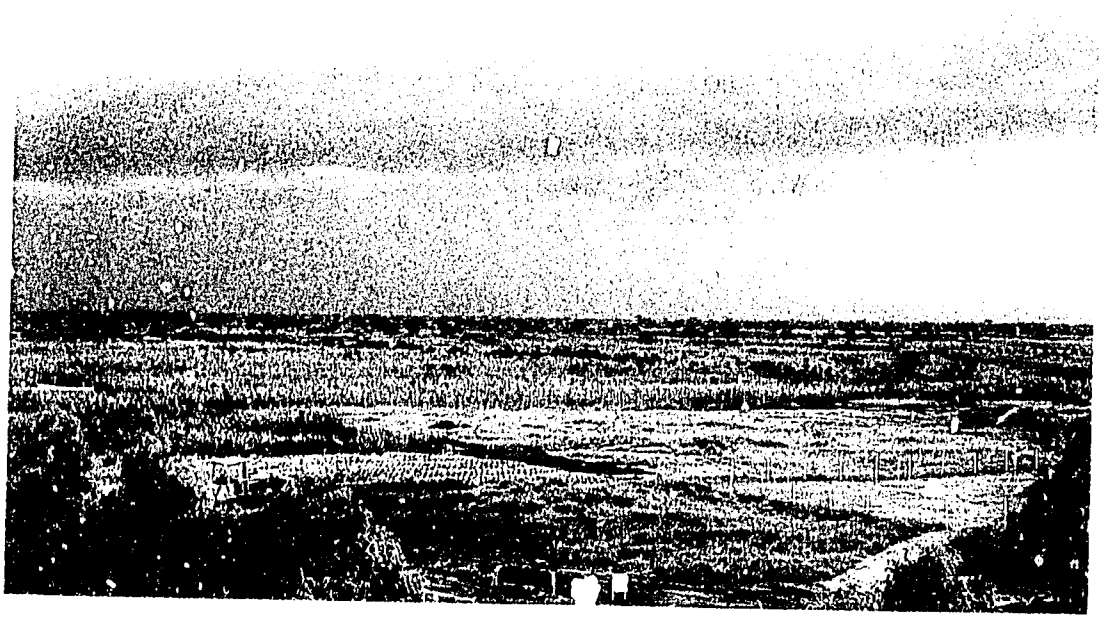
It will also be an important in-service training center for West African scientists and technicians, specializing in research and production methodologies and statistical techniques. Several advanced students from the University of Niamey are currently gaining valuable research experience as they carry out thesis work under the guidance of ISC scientists.

ISC's research programs have a single aim: stable and ample yields of food crops for the millions of subsistence farmers who live in the arid and semi-arid regions just south of the Sahara, where continuing droughts, depleted soils, and extremely high temperatures have caused much human misery in recent years.

*In research efforts to reduce the effects of strong winds and sand blasts on crops, barriers or fences (as at extreme left) are created. Sophisticated instruments are used to measure windspeed and soil moisture levels.*



*Heavy rainstorms in the Sahel are signaled by huge cloud formations, such as the one above. Below, preparatory work at the ICRISAT Sahelian Center, near Niamey, Niger, as the storm approaches.*



## Experimental Crops Thriving

The foundation stone for the Center was laid in August 1983 and construction is in the early stages, but research is already in full swing, with experimental crops thriving in the fields. Though 1984 was the driest growing season in memory, on-station work with pearl millet and cowpea resulted in yields up to four or five times those of nearby farmers who used traditional methods.

The governments of Finland, France, West Germany, Italy, Nigeria, Norway, and Switzerland and the Arab Bank for Economic Development in Africa are assisting in financing the laboratories, offices, library, and conference facilities being built at Sadoré, 45 kilometers southeast of Niamey. Other major donors of the CGIAR—including Canada and USA—have promised assistance. Construction will cost about $6.5 million and will take more than 18 months to complete.

The 500-hectare site was donated by the Government of Niger, which has expressed strong support for the venture.

## Interinstitutional Cooperation

ICRISAT recognizes that the complex food problems of Africa will be solved only by mobilizing the talents of experts from many fields and research institutes. In addition to ICRISAT scientists, the team at ISC includes researchers from the International Livestock Center for Africa (ILCA), the International Institute for Tropical Agriculture (IITA), the International Fertilizer Development Center (IFDC), Institut Français de Recherche Scientifique pour le Développment en Coopération (ORSTOM), and the Universities of Hohenheim (Germany) and Texas A&M (USA).

Though they represent many institutions, the scientists are all working in a coordinated, cooperative effort to solve the difficult problems of the Sahel. They are doing baseline studies that will enable them to develop seed varieties and farming technologies that assure reliable yields—enough food for rural families in bad years and an abundance in good years.

## Pearl Millet: A Hardy Crop

Pearl millet is a miracle crop. It survives in areas so dry that few other food crops can produce grains, growing in hot, sandy soils in spite of extremely high surface temperatures and fierce sandstorms. With properly distributed rainfall it can grow with as little as 250 mm of rainfall a year.

"The development of a new and reliable high-yielding millet can contribute as much to raising the living standards of millions of poor people as the changes in structure and policies that are also necessary," the World Bank reported in 1978.

Fifty percent of the world's pearl millet hectarage is in Africa, and it is most important in the Sahelian regions of Niger, Mali, Burkina Faso, Senegal, Chad, Mauritania, and Nigeria. Millet grain is usually pounded in a deep mortar, made into flour, boiled, and eaten in the form of a porridge-like gel.

Substantial improvements in pearl millet yields have generally eluded past researchers in the region. Varieties from eastern Africa and India are poorly adapted to the conditions of sub-Saharan Africa, where as seedlings they are destroyed by sandblasting and high soil surface temperatures.

Breeding efforts at ISC concentrate on developing early-maturing varieties (80 to 100 days) resistant to downy mildew, smut, ergot, and *Striga*. Germplasm from ICRISAT Center in India is being introduced into local stock, taking advantage of the environmental strengths of African native species and adding high-yielding qualities of exotics. In addition, an ORSTOM researcher at ISC is studying local genetic diversity in the vigorous wild millets of Niger, Mali, and Burkina Faso.

A small germplasm bank at ISC will be used for on-site evaluation of local varieties and to provide genetic material for national programs in West Africa.

## Cowpea: Good to Eat, Good for the Soil

Cowpea is popular where rainfall measures from 300 to 700 mm. Cowpea research at the Sahelian Center is conducted by IITA, which has the mandate for this hot-weather crop that grows well in poor soils. Cowpea is rich in protein and is ground, boiled, or eaten in sauces served with carbohydrate diets. Its leaves can be eaten like spinach; the young pods resemble snap beans, and the hay and haulms are useful for animal forage.

Its major drawback is its susceptibility to insect damage in the field and in storage. Because of this, cowpea production is seldom a priority, either for farmers or policymakers.

Poor farmers have little access to pesticides, so IITA has developed cowpea varieties with individual resistance to some of the most important insect pests, such as thrips, aphids, and bruchids. It is also developing cultivars with multiple resistances to these pests.

In the Sahel, farmers are often faced with shortage of water for their insecticide spraying operations. Because of this, an electrostatic insecticide application method that does not require water is being used.

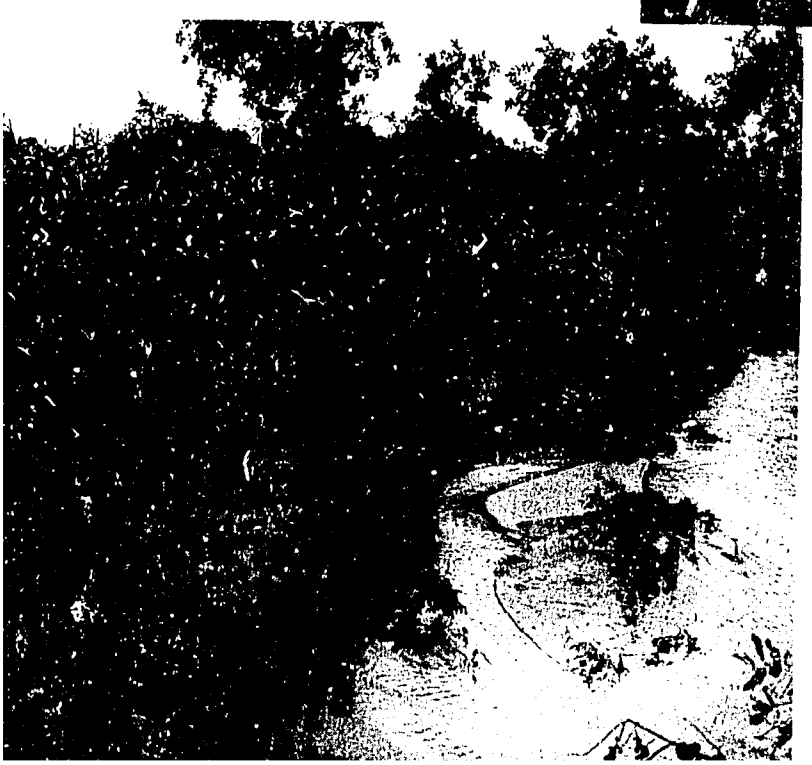
*ICRISAT scientist examines pearl millet in a wetter region of Niger, where the crop growth is luxurious and yields are high.*

Over 90% of cowpea in the Sahel is intercropped with cereals, particularly millet and sorghum. Traditional varieties take 100 to 150 days to mature. Researchers are evaluating short-cycle varieties (55 to 70 days) that can be planted in late June and produce pods by August, giving consumers something to eat before the millet harvest in October. One variety being evaluated has given on-station yields of seed as high as 1 tonne/ha in 60 days, compared with 200 kg/ha from a local, longer-duration variety.

Cowpea has two additional advantages. It cooks quickly (in 20 minutes to one hour), saving scarce fuel, and as a legume, it provides its own nitrogen by fixing it directly from the atmosphere through the plant root zone, leaving residual nitrogen to enrich the soil for the crop that follows.

## Looking for "Hot Spots"

ISC's entomology program searches out "hot spots" of infestation of pearl millet by two major pests, earhead caterpillar and



*Rainstorms result in heavy runoff and erosion, even on the sandy soils of the Sahel (left). Valuable top soil and organic matter (displayed above by a farmer in Kolbila village, Burkina Faso) are washed away, accentuating the problems of crop production in an environment already poor in resources.*

stem borer. All of the millet fields east of Niamey in West Africa are severely infested with the caterpillar and nearly 90% with stem borer. These are useful sites for identifying resistant cultivars, including promising early-yielding varieties ISC is developing that escape pest damage by maturing before infestation becomes serious.

Use of resistant varieties makes it possible to control pests with little or no insecticide—a safer practice ecologically and an advantage for farmers who cannot afford chemicals and frequently are illiterate.

ICRISAT's entomologist is also studying effective natural enemies (parasites, predators, or pathogens) that could reduce the level of pest populations without destroying the balance of natural forces.

*Sowing millet the traditional way on a clayey soil near Gaya, Niger.*

## Managing the Natural Environment

Sahelian soils are poor in nutrients, about 90% sand and, once denuded, are easily eroded. Barren creeping dunes near Sadoré are vivid evidence of the desertification that is taking place in this dry area.

The IFDC scientist working at Sadoré believes these poor soils are probably a greater limitation to increased productivity than the lack of water. He is convinced, however, that soil fertility can be improved.

For generations, slash-and-burn and bush-fallow systems gave the land a chance to rest and revive between crops, but as population pressure has increased, periods of idleness have been shorter and shorter, and the land has become progressively exhausted and unproductive. An official of the World Bank recently called the complex interactions among soil, rainfall, climate, and temperature "a neglected area where not enough work has been done."

## Enriching Soils

IFDC, with ICRISAT's assistance, is investigating effective use of nitrogen and sulfur fertilizers and searching for efficient and cheaper sources of phosphorus. IFDC's researcher believes that the lack of phosphorus is a more serious problem in Sahelian soils than the shortage of nitrogen. His field experiments show phosphorus is extremely effective in increasing yields of cowpea and pearl millet.

One of the largest deposits of phosphorus rock in West Africa is in Parc W, near Niamey. IFDC found that grinding this rock and treating it with sulfuric acid to increase the availability of its phosphorus for crops is a potential alternative to commercial phosphorus and fertilizer. The Government of Niger is considering the feasibility of developing a pilot plant for manufacturing this par-

tially acidulated rock phosphate, using readily available local resources.

## Crop Residues

Another means of enriching soil is by using crop residues left after harvest. Pearl millet yields increased significantly on experimental plots when residue was left on t' e field, and use of fertilizer plus crop residue yielded 1.8 tonnes/ha, compared with the typical local yield of about 300 kg/ha.

Farmers customarily use crop residues for roofing, fences, fuel, and animal food, so this technology cannot be effective without some change in traditional practices.

## Taming the Winds

ICRISAT staff, aided by scientists from the Universities of Wageningen and Texas A&M, are developing soil management technologies at ISC to improve plant establishment and stabilize sandy soil surfaces.

First rains in the Sahel generally come in early June at the end of a long, hot, dry season when little vegetation is on the ground. The rains are preceded by winds that reach velocities as high as 100 km/h. Seedlings are blasted by sandstorms and are subsequently buried, leading to low plant populations.

To limit wind damage and reduce erosion, scientists experimented with roughening the soil surface by fo.ming ridges, incorporating crop residues, and using an implement called a sandfighter. Ridging not only reduced wind erosion, but also helped control weeds. Crop residues trapped blowing sand and lowered surface soil temperatures, which sometimes reach 55°C.

A Hohenheim University collaborative agronomy study at ISC is evaluating whether rapidly growing shrubs or trees, planted at strategic locations on continually blowing sand, can protect seedlings during their early development. The scientists are evaluating various trees and shrubs as well as

*Two scenes near Gaya village, Niger: below, harvested pearl millet is stacked to dry in the sun; at right, a happy farmer with his millet harvest.*

agronomic practices such as ridging to determine how they affect crop performance.

Another approach to reducing wind damage and conserving water is being studied by the ICRISAT agroclimatologist, who is experimenting with an adapted version of the traditional fence used to stop snow drifting in winter on the open plains of North America.

## Effects of Tillage

ISC studies have shown that tillage, even on sandy Sahelian soils, reduces water runoff, increases infiltration rates, and helps pearl millet roots develop more rapidly.

Ridging and other tillage, however, are difficult for most Sahelian farmers, who prepare their fields manually, don't use animals for draft power, and cannot afford tractors. Labor shortages, especially at weeding time, are a major limitation to increased production in

*Firewood constitutes the main source of energy in the Sahel. Consequently, trees are cut indiscriminately and the wood carried away for trading.*

the Sahel. Animal draft power could make up for the shortage of labor, improve the quality of traditional farming, and enable farmers to use new methods to increase productivity.

## Showing What Can be Done

The contrast between a typical farmer's field near the Sadoré site and an ICRISAT experimental plot on the station that used improved management techniques was striking. Both were planted the same day. In late July, the farmer's field had only a few scraggly, scattered millet plants, but on the ridged experimental plot at Sadoré, with improved seed sowed at planned densities, timely cultural operations, and judicious use of fertilizer, the vegetation was deep green, thick, healthy, and almost a meter high.

The Sahelian farmer won't do that well with improved technology, the ISC agronomist cautioned. On-station work must be verified at several locations and over three or four seasons to account for soil variability. But ISC researchers are finding alternatives that can reduce the gap between on-station and farmers' yields and help farmers get the best possible results from the inputs they can afford.

## Studying the Weather

A sophisticated, computerized weather station, the first of its kind in West Africa, records hourly data on wind speed and direction, solar radiation, air temperature, and humidity at Sadoré. In cooperation with national programs, the ISC agroclimatologist has analyzed long-term rainfall data for a number of locations in Niger, Mali, and Burkina Faso and provided information on rainfall amounts, probabilities, and soil-water balance.

This information is published by ICRISAT to help national scientists in the three countries. With it they can predict the best dates for sowing and the conditions under which diseases and pests will be a serious threat, and design ways to use the scarce rainfall efficiently.

The Center, which will add its first groundnut specialist to the staff in 1986, was host recently to an international symposium on Agrometeorology of Groundnut sponsored by ICRISAT and the World Meteorological Organization. It brought together 80 experts to discuss weather factors that limit groundnut production in seasonally dry, rainfed areas.

## In the Villages

Crop management and livestock nutrition are being analyzed by the ISC economist and the ILCA animal scientist in four Nigerien villages with average annual rainfall between 400 and 600 mm per year.

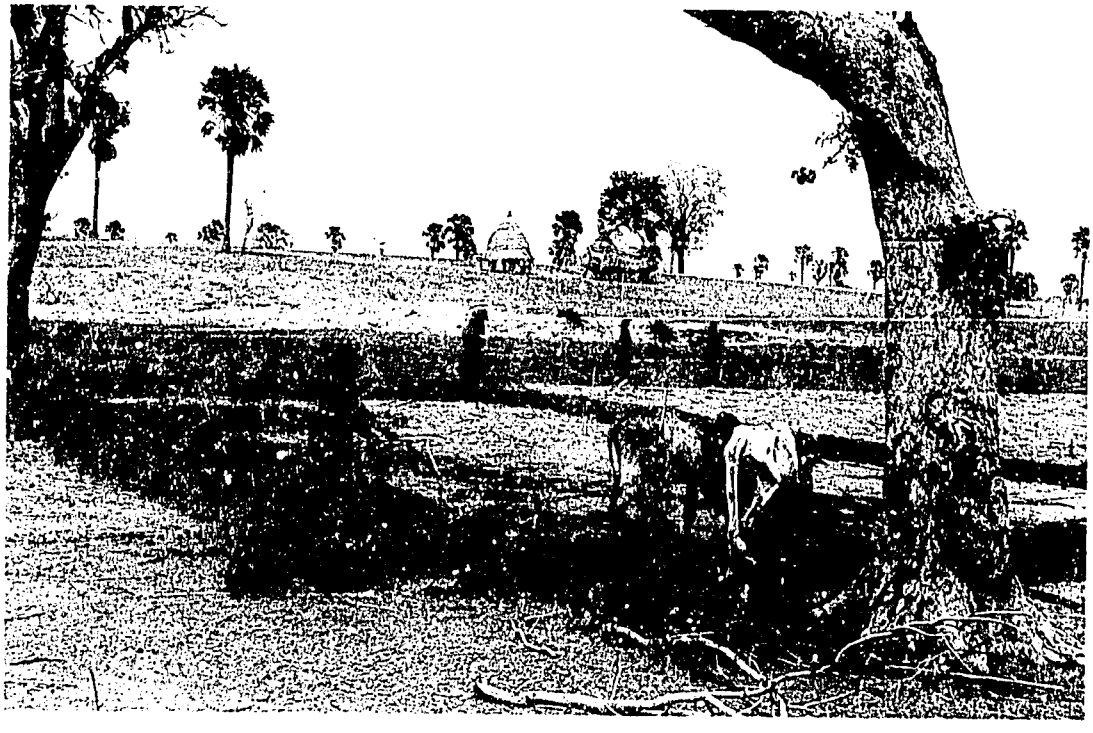
Trained survey researchers fluent in the local language are posted in each of the villages, where they have established friendly relationships with about 120 sample households. They monitor on-farm results of fertilizer use, variations in planting dates and densities, pest and insect damage in the field, and analyze buying and selling habits.

The data they collect help researchers understand villagers' practices better, so that ICRISAT's research can be developed in a manner appropriate for the culture of the Sahel. In the end, however, teaching new methods to the farm community is in the hands of national governments and extension agents.

## On-Farm Tests

On-farm trials of ICRISAT-improved varieties and technologies have been both researcher-managed, with work supervised by a trained technician to maintain scientific

*With heavy dependence on firewood, trees get scarce, speeding up erosion and impoverishing the soil (above). A tree nursery has been established at ICRISAT's Sadoré research station (below). Agroforestry systems, incorporating trees and shrubs with food crops, are being studied. Trees can serve also as wind or sand breaks.*



*Animal traction is used only rarely in Sahelian agriculture. Most farm operations are manual. Below, weeding of a millet crop is done using a traditional hoe that also tills the soil lightly at the same time.*

standards for valid comparisons, and farmer-managed.

Early results showed that use of available improved varieties gives no yield advantage over local cultivars unless phosphorus fertilizer is used, but with phosphorus, yields increase substantially. Though 3 years ago only about 10% of farmers in the villages studied used any kind of fertilizer, today about 80% of them use some supplement.

## Animal Nutrition and Draft Power

ILCA's studies of animal nutrition in the four villages consider the economic role of pastoral practices. More than 90% of the households surveyed had some livestock—donkeys, sheep, goats, cattle, poultry, and in the northern villages, camels and horses used for transportation.

Animals tend to be looked on as an asset, "money in the bank" that can be liquidated to pay for weddings, funerals, or taxes. Of animals slaughtered, the vast majority are killed for the Muslim feasts of Ramadan and Tabaski. Others are used in religious sacrifices, for baptisms, and to honor visitors. Animals are rarely used for cultivation.

Feed, especially in the dry season, is a serious problem. When it is time for planting, animals are weak and unable to work in the fields. One solution being considered is to encourage cultivation of a crop such as cowpea that is useful for both human food and animal forage.

The ILCA program is also analyzing, in cooperation with soil chemists, how fertilizer used on millet crops influences nutritive values of residues the animals eat.

*Livestock graze near the Niger riverbed. During 1984, the Niger river stopped flowing through Niamey for the first time, and a dam was built to help the city's water supply.*

*Pearl millet stalks used as fencing material in Nigeria. Sorghum stalks are also used in other parts of Africa for fencing or roofing.*

In addition, ILCA is evaluating the profitability, in terms of both time saved and increased yield, of using animal traction (donkeys or cattle) in pearl millet cultivation.

Farmers with hand tools can cultivate only a limited area. With animal draft power, the time needed for soil preparation can be reduced by 14% with one donkey, or as much as 50% with a pair of bullocks. Farmers could cultivate and weed more efficiently, possibly expand the area they crop, and increase their efficiency and food production measurably if they used animal traction.

## Working Together

No single research effort at ISC will solve the complex problems of how poor farmers in the Sahel can produce enough to eat. By working together and cooperating with national programs to develop stable, resistant, higher-yielding cultivars and show how farmers can enrich the soil, conserve water, and cultivate crops efficiently, the scientists based at ISC hope to come up with a workable strategy for increasing productivity that will also improve the quality of life for millions of people.

# Burkina Faso: A West African Transitional Zone

ICRISAT's team in Burkina Faso operates from a small national research station at Kamboinse, just outside Ouagadougou, where its research is directed at increasing and stabilizing yields of both pearl millet and sorghum in a broad region with considerable variation in soils and rainfall.

Support for ICRISAT's work there is provided by regular core funds from the CGIAR, and by the Canadian International Development Research Centre (IDRC), the United Nations Development Programme (UNDP), the Leverhulme Trust, and the Organization of African Unity Semi-Arid Food Grain Research and Development (OAU-SAFGRAD) project, a U.S. AID-funded operation that covers 25 member countries in dry areas across Africa from the Atlantic to the Red Sea and the Indian Ocean.

The oldest of ICRISAT's West African regional programs, the Kamboinse operation has done landmark work on control of the parasitic weed *Striga* (witchweed), a problem throughout the semi-arid tropics. Its breeders have also developed two promising early-maturing pearl millet varieties that are in advanced testing stages and three sorghum varieties that offer higher and more stable yields than local cultivars.

In Burkina Faso, ICRISAT is dealing with

*Experimental sorghum varieties being grown at the Kamboinse Research Station in Burkina Faso.*

*Sorghum scientists examine a promising variety grown in on-farm trial in Kamboinse village, Burkina Faso*

two environments: millet areas, with low rainfall, dry, sandy soils, poor water retention, and extremely difficult growing conditions; and sorghum-cultivating areas, where rainfall is higher, soils are better, with more clay and silt, greater water-holding capacity, and less extreme atmospheric conditions. The transition between extreme environments from north to south is gradual, so both millet and sorghum are grown in most areas and their relative importance is a function of differences in both rainfall and soil.

Burkina Faso itself is the second largest producer of sorghum and fourth largest producer of pearl millet in West Africa. The two crops combined make up more than 80% of its total agricultural production.

Although agricultural scientists are concerned with all aspects of research, emphasis on pathology, entomology, plant physiology, farming systems, and weed control becomes increasingly important in wetter areas, where more crop diversification and flexibility are possible.

## Establishing a Research Network

Service to national scientists throughout the area is a major effort of the Burkina Faso program. Small countries with young and relatively unsophisticated agricultural programs gain a great deal from the expertise and support that ICRISAT offers.

Farmers have been invited to visit ICRISAT's fields on the station to inspect improved sorghum varieties, and workshops and symposia are offered for scientists.

Another activity designed to strengthen West African research was a regional sorghum workshop at Ouagadougou late in 1984. Its aim was to give sorghum researchers a chance to discuss problems and establish an effective information network in the region.

Representatives from 16 countries—big producers of food crops such as Nigeria, Burkina Faso, Ghana, and Mali, and small ones such as Cameroon, Guinea, Gambia, the Central African Republic, and Mauritania—attended, along with representatives from regional and international organizations and ICRISAT Center.

After ICRISAT described its training and research activities and the role of the research network, national and international program scientists presented papers and toured sorghum fields to see on-farm activities. ICRISAT, which is contemplating expanding its sorghum research in West Africa, will coordinate activities of the proposed research network. A second annual sorghum workshop was held in Bamako, Mali in 1985. These annual workshops are a key element in the proposed network.

Some training for technicians is offered by the Burkina Faso program, but most training is done at ICRISAT Center in India, where a large contingent of West Africans participates in both long-term and short-term courses.

## Intermediate Varieties Needed

The sensational results of the Green Revolution have never been available to the resource-poor farmers of Africa. The immediate goal of research there is based on low-input, low-technology agriculture.

For farmer acceptance, new crop varieties must demonstrate yields equal to or slightly better than local cultivars when managed in the traditional manner. And for acceptance of improved, affordable management technologies, such as use of fertilizer and tied-ridging, the gains must be more significant.

Scientists in Burkina Faso aim at developing "intermediate" varieties and simple practices that can benefit the farmer now, before more spectacular, high-yielding varieties are developed for semi-arid zones of Africa.

## Improving Pearl Millet

The pearl millet improvement program in Burkina Faso deals with farmers who can't afford risks and who must cope with extremely unpredictable rainfall. Often they delay sowing because first rains are late, or they replant when drought sets in after seeds germinate.

The greater the delay in planting photoperiod-sensitive millet varieties, the greater the yield reduction. If drought comes at the end of the season, it can mean total crop failure.

The Burkina Faso program is seeking to develop two types of millet to deal with this situation: photoperiod-sensitive, full-season varieties (about 140 days to maturity) suited to sowing with early rains (late May to 21 June); and varieties that are less sensitive or insensitive to photoperiod, are of shorter duration (80-110 days) and can be sown late or as a short-cycle relay or intercrop.

An early-maturing ICRISAT variety, IKMV 8201, is now in advanced trials in farmers' fields and seed has been sent to national programs and FAO for testing. It has given nearly double the yields of local millets and shown vigorous growth, has satisfactory food quality, is resistant to *Striga*, and is able to escape drought during its early stages.

Breeding improved, late-maturing varieties is proving to be much more difficult, and progress is expected to be slow. Nevertheless, some promising populations developed through recurrent selection, such as IKMP 2, IKMP 3, and IKMP 4, are now ready for on-farm testing.

## Food Quality

Food quality in pearl millet is important for making *tô*, a traditional porridge, beignets (fried puffs made with a batter of millet and cowpea flour), and beer. Consumers have strong preferences—yellow grain is preferred in the north, gray in the south. In sorghum white grain is generally preferred over brown or red, although both are consumed.

When 8 or 10 ICRISAT varieties are ready for food-quality judging, village women cooperate with scientists; they prepare the *tô* or beignets, then taste the food while blindfolded so as not to be influenced by color. The tests allow scientists to determine which varieties are acceptable, and this information is used by breeders in developing improved varieties.

## Improving an Improved Cultivar

Several years ago ICRISAT proposed E 35-1, an introduced sorghum cultivar from Ethiopia, for cultivation on the comparatively rich soil near houses in Burkina Faso villages. It produced well with plowing and fertilizer application, but experience showed it would be more acceptable if it gave good grain yield under traditional management and if improved seedling establishment and *Striga* resistance were bred into the line.

The variety that breeders developed, based on E 35-1, was called ICSV 1002 HV. It has been tested in Burkina Faso, Cameroon, Sudan, and Nigeria, and has outproduced both E 35-1 and the local variety by 9% over a 3-year period. In two areas of Burkina

*ICRISAT economist discusses sorghum crop with a farmer in Koho, Burkina Faso, who is also the village chief.*

Faso, it was comparable or superior to local varieties under traditional management and responded to fertilizers better than local varieties, making the use of fertilizer economical.

Another promising cultivar, introduced from South Africa, is ICSV 1001 HV, called Framida, which since 1977 has been tested in Mali, Ghana, Nigeria, Cameroon, Togo, Sudan, Ethiopia, and Kenya as well as Burkina Faso. Tests in Burkina Faso farmers' fields showed increases in grain yields from 3 to 40% with traditional management, and 15 to 45% with improved management. Seedling establishment was superior and Framida was found resistant to *Striga*. In Sudan, Ethiopia, Mali, and Burkina Faso it produced appreciable yields in very dry years between 1978 and 1982.

## Struggling against *Striga*

*Striga*: Some people think of it as a mere nuisance, but farmers know that the devastating parasitic weed can wipe out an entire crop and knock fields out of production for years.

This parasitic weed attacks all cereals and is extremely serious for sorghum and pearl millet in West Africa. It attaches itself to the roots of the host, robbing the plant of water and nutrients.

Each *Striga* plant produces from 40 000 to 1 million minute seeds, which are carried on the wind, rain, cattle, or man. Seeds germinate only if they find a host crop, but they remain viable in the soil for many years. *Striga* thrives even in poor soil and is particularly damaging when moisture is insufficient.

ICRISAT began intensive research on *Striga* in India in 1977 and has stationed a scientist for *Striga* research with the Burkina Faso program since 1979. ICRISAT's pocketsize illustrated *Striga* Identification and Control Handbook is an invaluable help to researchers and extension agents in Africa, Asia, the Arabian Peninsula, and parts of USA.

The prime strategies against *Striga* are a combination of host resistance and improved agronomic management. Trials of the International Sorghum *Striga* Nursery are carried out at several locations in Burkina Faso, including Farako-Ba, which is also the site of ICRISAT's pest management work in Burkina Faso.

*Striga*-resistant ICSV 1001 HV and ICSV 1002 HV are being multiplied in Burkina Faso, as is ICSV 1001 HV in Togo. During the drought in Burkina Faso, ICVS 1002 HV continued to demonstrate yield stability. It produced 3600 kg/ha on the Farako-Ba station when cultivated with animal traction, and 2500 kg/ha with manual cultivation. The local variety gave 1600 kg/ha and 1360 kg/ha under the two systems. Farmers also like this cultivar because of its desirable grain and fodder qualities.

Millet varieties that combine high levels of *Striga* resistance, good yield, and satisfactory food quality are yet to be found, though some promising lines have been identified, and ICRISAT's selection, testing, and genetic analysis will continue.

Management techniques ICRISAT recommends include rotation with trap crops (crops that germinate *Striga* seed but do not serve as a suitable host), such as cotton and groundnut. By planting trap crops in adjacent rows and rotating the sorghum from row to row each year, farmers can reduce *Striga* buildup considerably.

## On the Farm

On-farm studies by ICRISAT economists go hand-in-hand with crop improvement work. In the six villages studied in Burkina Faso, farmers used 40 different varieties of white sorghum, 19 of red sorghum, and 27 of pearl millet, choosing specific varieties for different periods in the planting sequence.

Breeders can identify well-adapted local materials from studying these farmer practi-

*Women set out to sell their processed food.*

ces and make sure that they test new varieties against appropriate local cultivars.

Another study considered the puzzling question of yield gap—the difference between what happens to an elite variety on the research station and on the farm. Yield reductions of 40 to 60% are common, even when crops are cultivated at similar levels of fertilizer application. The ICRISAT economist looked at five management factors: fertilizer timing, deep plowing, tied ridges, planting arrangement, and timing of weeding.

The most significant management factors, this study found, were the use of tied ridges and deep plowing. Neither tied ridging (building up a slight ridge and furrow and closing the furrow at intervals to retain water) nor deep plowing is generally practiced by sorghum farmers in Burkina Faso, although they have been found useful in some other African countries. The reasons are primarily the shortage of labor, poor health of animals for traction at planting time (when food supplies are at their lowest), and the fact that traditional sorghum varieties show marginal responses to these techniques.

The study called for systematic screening of varieties under low-tillage conditions. It noted that continued selection and development of new varieties solely under conditions of deep plowing and tied ridges makes it impossible to screen for varieties realistically suited to the needs of the farmer, who does not have the money or manpower to introduce the soil management technologies available on research stations.

# Mali: Integrating National and International Research

ICRISAT's Mali program, a bilateral venture with USAID funding, is closely integrated with the young Malian agricultural research system and has been described as "extremely cost effective."

Its sorghum and millet breeding work show "substantial promise of making a significant contribution to the development of improved varieties for a wide belt in West Africa," and its agronomy project "has made a major contribution to the development of Malian agronomic research capabilities."

These quotations are from an outside evaluation of the program, prepared for USAID, that suggested the Mali model may prove to be "one of the most viable approaches ICRISAT could follow in the development of its African research and training program."

The program tests breeding lines of its major crops for food qualities and consumer preferences and is encouraging production of pigeonpea and finger millet, two crops that can add variety and protein to the Malian diet, enrich the soil, and give farmers greater flexiblity in contending with erratic rainfall.

## Assisting and Sharing Stations

The program operates at Sotuba, near Bamako, where it shares fields on a 30-hectare

*A former ICRISAT trainee in Mali examines a good sorghum panicle*

station with the national program, and at Cinzana, a new Malian research facility that ICRISAT helped develop. ICRISAT continues to provide logistic support to the Cinzana station, which also receives substantial support from the Swiss Ciba-Geigy Foundation. The ICRISAT-USAID operation has been completely integrated with the Malian program "There is no 'them-us' feeling," the ICRISAT team leader emphasizes.

For more than 7 years, ICRISAT Mali staff have supervised thesis work of university students from the Rural Polytechnic Institute at Katibougou, where ICRISAT breeding lines and technologies are often tested as part of academic work. Other stations representing contrasting climates, with different insect and disease complexes, are also frequently used for yield testing.

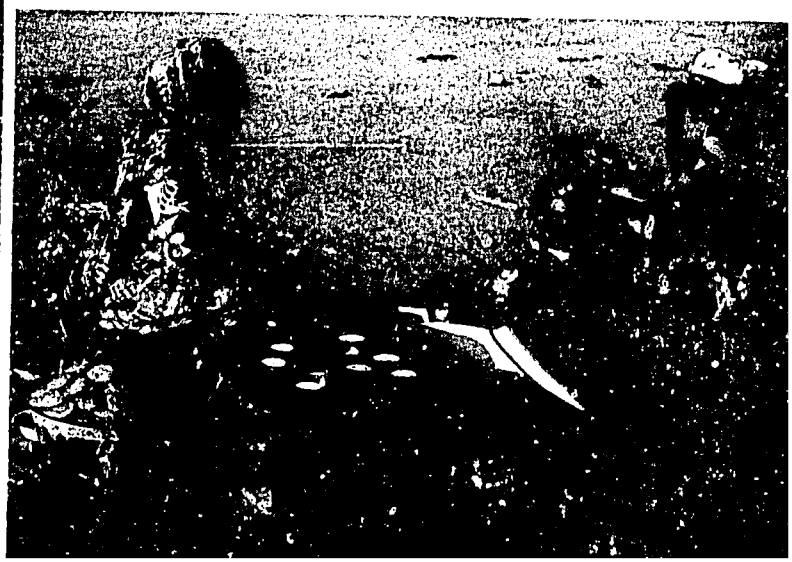
Upgrading the national program increases Mali's ability to carry out worthwhile research and to absorb germplasm and trained talent now coming from universities and scientific institutions In addition to sending Malian scientists for advanced-degree work in the United States and France, the USAID-ICRISAT program has financed 6- to 8-month in-service training at ICRISAT Center, in India, for more than 40 Malian scientists and technicians since 1977.

## On-the-Job Training

Day-to-day work in the fields with the ICRISAT staff is a source of valuable on-the-job training for Malian assistants. Instead of preparing fields with rakes, they have learned to farm on furrows. They have gained experience on the station with animal traction and the wheeled tool carrier modified by ICRISAT from an earlier model developed in Africa by a French engineer. The 10 tool carriers used in the Mali research program have been so successful that the possibility of having them fabricated locally is under investigation.

The Cinzana research station, 275 km northeast of Bamako, is directed fulltime by a Malian scientist. ICRISAT's team leader from Bamako visits twice monthly to consult on work there, which is devoted to studies of animal traction, pearl millet breeding

*African women traditionally play a key role in food processing. At left, millet grain being pounded; below baking cakes from the millet flour.*



and agronomy, and diseases of millet and sorghum.

In 1985 a pathologist from ICRISAT Center on a short-term consultancy at Cinzana was successful in establishing, for the first time in West Africa, a pearl millet downy mildew screening facility. Similar short-term visits by scientists from ICRISAT's headquarters in India and the ISC are envisioned for the future as part of the program of building on the strong but limited Malian research base.

Small things can be extremely important in encouraging and supporting agricultural research in a poor country like Mali. Without adequate seed storage facilities, the Sotuba station was losing valuable material each year during hot, humid weather. An expenditure of $9000 by the ICRISAT-USAID program made it possible to equip a building for storing experimental seed at a consistent 15% humidity and 15°C temperature. Providing screening and off-season nurseries for disease studies at Cinzana is another example of of a modest but important contribution.

## Sorghum to Suit the Climate

Sorghum is an important crop in Mali, but improving it is not easy, and the breeder is confronted with some unique problems. The cultivar must fit the highly variable, wet-dry rainfall pattern; it must be early enough to escape end-of-season drought; it must resist the headbug and mold effects of late-season rains; its stem must be tolerant to tunneling by stem borers; the head must be loose and open to dry quickly and resist insect infestation; the plant must be resistant to or tolerant of foliar diseases; it must be easy to thresh, with hard seeds and flinty texture.

West African Guineense sorghums are well adapted to local conditions, but are low yielding, frequently giving less that 600 kg/ha. Though they are hit by diseases, the Malian sorghums are damaged on the lower leaves only, and upper leaves stay green. Under drought at the end of the season, the lower leaves of local sorghums quickly senesce and the plant is able to produce small but sound grain. High-yielding exotic varieties either die or produce chaffy grain in times of severe drought. Long glumes (tiny leaves that surround the seed) of landrace Malian varieties keep insects from eating the grains, and thick hulls are easier for Malian housewives to process.

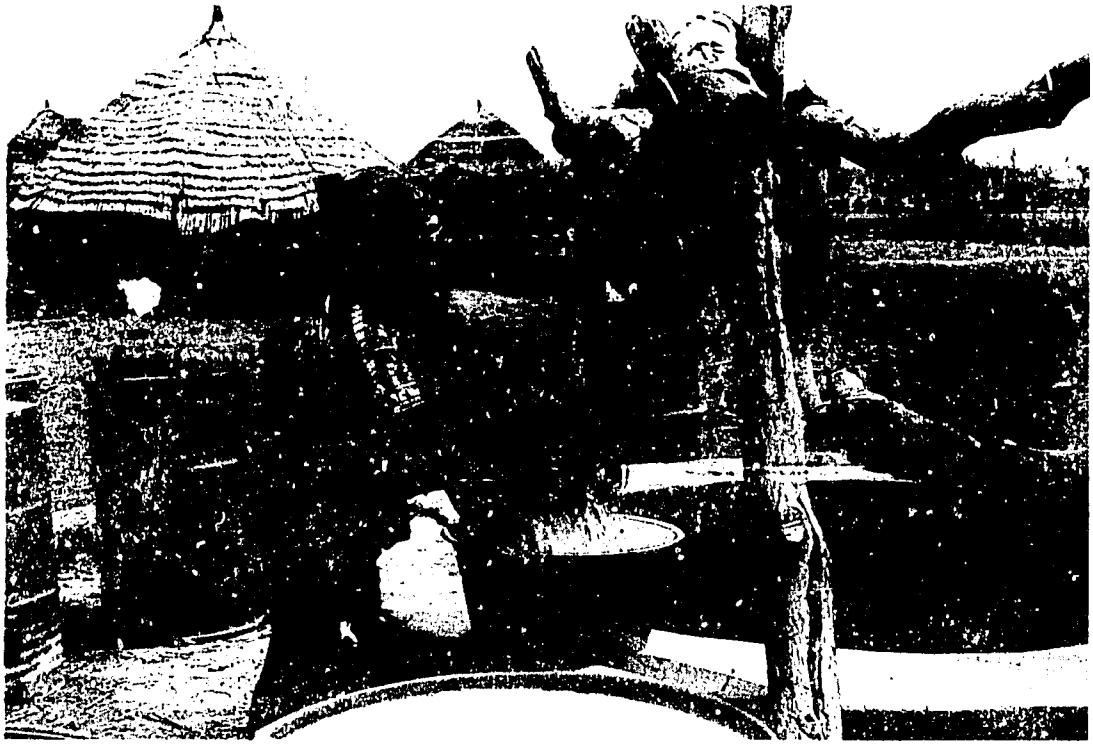
As a result of detailed studies of local sorghums, ICRISAT's breeding effort in Mali has emphasized sturdy local West African sources for basic germplasm, trying to incorporate the high-yielding traits of varieties from India and North America into improved cultivars.

## Sources of Breeding Material

ICRISAT Center in India is a world repository for the genetic resources of its mandate crops. Its sorghum gene bank with more than 27 000 accessions, 66% of African origin, is a resource from which breeders can draw for characteristics such as plant type, maturity, grain size, and resistance to physical and biological stresses that reduce yields. The stability of new varieties must be evaluated at many locations and under different conditions, especially in hot spots in Africa where the intensity and variety of diseases and pests is more severe than elsewhere.

It takes many years to develop new varieties. The ICRISAT breeder in Mali spent more than 6 years trying to breed a sorghum cultivar suitable for the area. Now seven promising lines (Malisor 84, 1-7) with confirmed grain quality and good agronomic performance are being yield-tested on a large scale preparatory to release.

Breeders concentrate on identifying desirable local pearl millet stock, isolating and recombining genetic material to develop specific traits, and finding resistance to downy



*Fetching water from the community well, another task left to women and children.*

mildew, smut, and lodging (falling over). Cinzana is a leading West African millet research station, and five varieties are currently being tested for their agronomic performance, including IBMV 8001, released in Senegal, and ITMV 8304, from Maradi, Niger, two varieties bred by ICRISAT scientists in collaboration with national scientists in those countries.

## Testing *Tô*

The ICRISAT Mali program was the first in West Africa to coordinate food quality research with breeding, and it has trained two Malian women technologists on its staff to test sorghum and millet varieties for nutritional value and food quality. They prepare *tô*, the traditional porridge of Mali, couscous, and gruel, to determine whether new cultivars make satisfactory food products. Using a mini *tô* test they developed, they can accurately predict *tô* keeping quality of 20-g grain samples.

Keeping quality is particularly important in Mali, since village women prepare porridge for the evening meal and keep it until the next day. Sorghum or millet varieties that make "weepy" *tô* are quite unsatisfactory. The preferred qualities for *tô* in Mali are not the same as those desired by housewives in Burkina Faso, who use a different method of preparation.

While preference for *tô* or couscous made from millet, sorghum, or maize varies from area to area, the decision often comes down to the question of availability and ease of processing. Maize is harder to grind, though many like its flavor, and couscous takes three separate operations to prepare. Sorghum *tô* can be ready in about 30 minutes once the grains are hulled.

## Pigeonpea's Potential

Recently the ICRISAT food technology staff turned its attention to finding a simple method of hulling pigeonpea, a rich source of protein, which is sometimes grown as a hedge around fields. Though it is grown and eaten in some parts of eastern Africa, it has never been a popular food in Mali because people did not know how to prepare it. The technologists visited villages and demonstrated how to dry, hull, and cook pigeonpea. Taste panels liked the peas served as a sauce with couscous or in ragout with mutton or chicken.

Pigeonpea has good potential for the area. The plants can be used for fodder or green manure, and the woody stems are useful for fuel and for making wickerware, baskets, and fences. Because pigeonpea is a legume, it can fix most of its own nitrogen and may leave as much as 40 kg/ha of nitrogen in the soil for the crop that follows. It is an ideal intercrop with cereals because it grows slowly and is drought resistant.

After several years of testing, the Mali program has confirmed the excellent performance of ICRISAT pigeonpea variety ICP 148 and the Mali seed source is being distributed to national programs in Cameroon, Guinea, Togo, and Ivory Coast.

## Intercropping Millet and Maize

A maize/pearl millet intercrop is an optimal cereal combination for efficient use of land in southern Mali, and the ICRISAT agronomy program has carried out tests to develop a package of technologies for this improved

*The potential of pigeonpeas is being explored in West Africa. The seeds are a valuable source of protein, the plants can be used as fodder or green manure, and the woody stems serve as fuel.*

cropping system. On-farm testing of the system in different locations of southern Mali has shown its superiority. Early maize can be harvested as a cash crop or for food during the "hungry season," while millet is a preferred staple food that will be ready later.

The system offers some built-in security for the farmer who has only a hectare or two of land. If the maize fails because of drought or disease, the hardy millet can still provide a substantial yield. Other intercrops that are being tested are millet/cowpea, suited to the north, and sorghum/cowpea in regions of more moderate rainfall. The cowpea intercrop is a "bonus" after the main crop, and ICRISAT's agronomist is analyzing different planting dates and densities to find which give the best yields from the paired crops. Intercropping sorghum or millet with groundnut has also shown promise, and tests are now under way to develop improved technologies for cereal/groundnut systems.

Weeds are a major problem, but manual labor is in short supply during the crucial period, and timely weeding is often impossible. Farmers are generally dependent on their families for all field work; wives and children spend long hours in the fields, planting, weeding, and harvesting. Using donkeys or oxen to pull equipment, as is done on the research station, would help, but few farmers can afford draft animals. Some herbicide is locally produced, but it has not been found economical for use on sorghum and millet. Assisting the Malian research program in finding labor-saving techniques for weed control is therefore part of the ICRISAT agenda.

# Other West Africa Activities

## Senegal

The complexity of breeding suitable millet cultivars is clear from ICRISAT's millet studies in Senegal, which tested synthetic varieties from several countries in regional trials at different locations. Material bred in Niger performed well in Senegal, but that bred in Sudan adapted poorly.

Extension agencies in Senegal have multiplied seed of two ICRISAT pearl millet varieties, IBMV 8001 and IBMV 8004. During 5 years of testing, IBMV 8001 averaged 24% and IBMV 8004 21% more grain yield than the improved local variety. Both showed superior resistance to downy mildew, had higher seed weight, and matured 7 to 10 days earlier than other varieties.

Another ICRISAT variety, IBMV 8401, was

*Nomads form a sizeable section of the rural population in many parts of Africa, affecting both crop production and animal husbandry.*

recommended for release along with H7-66, bred by the national program. The improved varieties not only produced more couscous—the steamed grain served with a vegetable-meat sauce in North and West Africa—but won praise for their superior taste. All four varieties have been recommended for release by the Institut Senegalais de Recherche Agricole (ISRA).

## Cameroon

ICRISAT's gene bank was the source of sorghum germplasm used in Cameroon, where the IITA breeder cooperated in a SAFGRAD/ICRISAT testing project. Sorghum is the main cereal crop in northern Cameroon, and varieties S 34 and S 35—two lines from ICRISAT Center, selected by an ICRISAT breeder in Nigeria—were grown in Cameroon in 1983 and 1984. Yields from S 35 were 85% more than local control varieties—1330 kg/ha compared with 720 kg/ha for the local control; S 34 yielded 70% more grain at three locations.

Based on multilocational trials, on-farm tests over a 2-year period, and agronomic data, the Government of Cameroon has asked for seed from each of these two high-quality, white-grained varieties, which are resistant to most foliar diseases and tolerant of stem borer.

# Sudan and Ethiopia: Successes in Sorghum and Pearl Millet

Translated from the Arabic, Hageen Durra 1 means Hybrid Sorghum 1. It may also mean survival for the people of the Sudan, who have in the last few years suffered from devastating droughts and subsequent famine.

Bred by ICRISAT and the Sudan Agricultural Research Corporation with financial support from UNDP, Hageen Durra 1 yielded more than 5100 kg/ha under irrigation in 1984, compared with about 1100 kg/ha produced by the local variety. Under normal rainfed conditions, it gave double the yield of local varieties.

Hageen Durra 1 was made from a parent that ICRISAT brought to Sudan from Texas A&M University in the USA and mated with a line of Nigerian parentage. It was one of three elite hybrids synthesized and evaluated from more than 3000 experimental hybrids grown in the Sudan between 1979 and 1982.

After 4 years of field trials and experimental seed production testing, this hybrid was officially released by the Sudan Plant Propagation and Variety Release Committee in January 1983.

*Seed production field at Wad Medani, Sudan. Hageen Durra 1, a hybrid developed there, has done exceedingly well under a general drought in Sudan, and large-scale multiplication of its seed is now under way.*

*A sorghum nursery in Ethiopia. Melkamash 79, a variety developed in Ethiopia, has been released to farmers, and is now being tested in 10 other countries in trials over four ecological zones.*

## Expanding Seed Production

Because of Hageen Durra 1's superior yields, the government of Sudan hoped farmers would be able to plant it on a large scale in 1985, but not enough seed was available to meet the need; attempts to have seed produced outside the country were not successful.

Enough seed was produced to plant more than 50 000 hectares, but authorities had planned to plant it on 6 to 10 times that much land. The government and a private company have joined forces to produce an adequate supply of Hageen Durra 1 for future cropping.

Even if the drought in the Sudan ends, the need for this improved seed will continue. Hageen Durra 1 is the hybrid acclaimed by the head of USAID as a breakthrough in sorghum research; its ability to produce under drought conditions is a tremendous advantage.

## Advancing Pearl Millet

Another ICRISAT-developed food grain produced well under drought conditions in Sudan and the National Seeds Corporation there plans to grow about 4 hectares of seed to meet the demand from farmers and extension workers.

It is a pearl millet named Ugandi that has been released by the Sudanese government for general cultivation. On a research plot near El Obeid in western Sudan, it was

reportedly the only millet to survive the extreme drought because of its earliness.

Ugandi was an East African pearl millet variety called Serere Composite 2 that was sent from Serere, Uganda, to ICRISAT Center's germplasm collections in India for breeding work. An ICRISAT scientist stationed in the Sudan selected it for its early maturity.

It was not known as a drought-resistant pearl millet, and in good years the record showed that other millets outproduced it. In extremely dry weather, however, it produced grain before the heat and lack of water could cause it to shrivel and die, as late-maturing varieties did. Serere Composite 2 was renamed Ugandi when the government released it for general use.

## And Sorghum

One of ICRISAT's earliest successes was a sorghum variety distributed internationally in 1979 that was released to farmers in Ethiopia. A long-headed variety with large white seeds, it was called Melkamash 79 by the government of Ethiopia. It is now in the Eastern Africa Cooperative Sorghum Regional Trials, being tested in four ecological zones in the 10 participating countries.

Two southern African sorghum germplasms (IS 9302 and IS 9323) transferred from the ICRISAT gene bank have proved superior in Ethiopian National Variety Trials and are now recommended for release there.

# SADCC-ICRISAT: Strengthening National Research in Southern Africa

ICRISAT's youngest regional program is dedicated to building up national capabilities in sorghum and pearl millet research in the nine countries of the Southern African Development Coordination Conference (SADCC).

The SADCC-ICRISAT program will provide research support and training for scientists of Angola, Botswana, Lesotho, Malawi, Mozambique, Swaziland, Tanzania, Zambia, and Zimbabwe so they can develop sorghum and millet varieties and hybrids suited to national needs.

The emphasis differs somewhat from that at the ICRISAT Sahelian Center in Niamey, which is carrying out more traditional, basic research in food production in the Sahelian environment.

SADCC-ICRISAT will concentrate on introduction and development of as much genetically diverse breeding material as possible, assisting each country's research program in solving its own problems of producing food for the future. More than 2800 germplasm lines from ICRISAT Center's collection have been supplied to the program; these offer a firm foundation for sorghum improvement in the region. Parallel to this, elite breeders' material has also been assembled for testing.

*Evaluating sorghum germplasm at the SADCC-ICRISAT regional sorghum and millet improvement program's research farm on Matopos Research Station, Bulawayo, Zimbabwe.*

*This sorghum variety, SPV 386, developed at ICRISAT Center, has been released to farmers in Zambia as ZSV 1*

## Getting Started

In 1980, Heads of State of the nine SADCC countries asked ICRISAT to set up a research center to serve their region. A cereals program was later proposed by ICRISAT as an alternative to the center, and the United States agreed to finance a major portion of it through AID. In February 1984 the Government of Zimbabwe made 45 hectares of land available to ICRISAT for this work on a government research station at Matopos, near Bulawayo.

The first ICRISAT scientist arrived a few months later; six staff members are now in place. By mid-1985 a farm service unit and crop-processing building had been completed, and construction of a main office building with laboratories and conference facilities, as well as 65 housing units for Zimbabwean staff, was moving forward rapidly.

The first regional sorghum introduction nursery, with 5500 entries from ICRISAT Center and 25 countries around the world, was sown at five locations in Botswana, Malawi, Zambia, and Zimbabwe late in 1983, before the project was formally started. Off-season crossing blocks were planted in April 1984 and again in 1985 at Mzarabani, a low-elevation location in northern Zimbabwe warm enough for year-round plant growth.

## Porridge and Beer

Sorghum, pearl millet, and finger millet follow maize in importance as cereal crops in the SADCC countries. Farmers grow both red and white sorghum, but white predominates. Thick porridge, called by various names (*ugali* in Tanzania, *nshima* in Zambia, *bogobi* in Botswana, *papa* in Lesotho, *sudza* in Zimbabwe), is made from both sorghum and millet, and both are also used for a nutritious opaque beer.

Sometimes people chew sorghum stalks like sugarcane. Dried leaves are used as cattle fodder, and stalks are good for weaving walls of houses or for roofing material.

In Botswana, where sorghum is the number one crop, sorghum flour is sold in plastic packets in grocery stores, and in some SADCC countries sorghum beer is also sold commercially. Sorghum beer is produced mostly from red and brown sorghum. *Chibuku*, an opaque beer popular in many southern African countries, uses most of the red and brown sorghum produced. It is unpasteurized and has a shelf life of only 4 to 5 days.

Pearl millet is more common than finger millet, ranging from 90% of the millet crop in Botswana and Mozambique to 60% in Tanzania. In recent drought years, when food shortages were severe, many countries in the region had to import both millet and sorghum.

Three of the SADCC countries—Zambia, Zimbabwe, and Malawi—produce sorghum seed on a commercial basis and want to develop hybrid sorghums to increase total national production. Commercial farmers get 5 to 6 tonnes/ha; small farmers' yields are in the 1- to 2-tonne range. There is potential for increasing yields on the farms of both commercial and small-holder farms.

Drought is a continuing problem in SADCC countries, where maize has been extended into marginal areas that could be better used for crops that require less rainfall. A more rational mix of improved maize, sorghum, pearl millet, and finger millet could better satisfy long-term cereal needs and could also be useful to the area's growing livestock industry.

## A Region of Great Diversity

In addition to planting trial nurseries the first year, the SADCC-ICRISAT program launched a series of workshops and tours for breeders. By getting to know their fellow researchers in nearby countries, the scientists of SADCC are forming a regional network for testing, setting priorities, and exchanging promising breeding stock and technologies.

The ICRISAT team leader has visited the SADCC countries and identified program needs and responsibilities. He has made it clear that the regional program is neither competing with national programs nor taking over local responsibilities.

Lesotho is rolling and in places mountainous, with intensive cultivation and terracing. Sorghum breeding material for high elevations from ICRISAT's collaborative work in Mexico may be well suited to Lesotho. Staffing breeding programs is a severe problem, since no sorghum breeding work has been done there. Two researchers have been identified for advanced study in the USA, and one of them is expected to become the country's first sorghum breeder.

Guineense sorghums—open, droopy-headed varieties—are grown from the coast through the center of Tanzania. Seeds from the ICRISAT work on Guineense in Mali will be evaluated for improving Tanzanian cultivars.

An agronomist who spent a year in Mozambique introduced sorghum and millet varieties from a number of places, including ICRISAT, in 1982. High-yielding, pearly white sorghum varieties from ICRISAT were less susceptible to grain mold and though seed from that introduction is no longer available, the pedigree is known and genetic material has been requested from ICRISAT Center for planting.

In Malawi, a large population in the Shire Valley depends on sorghum and millet for survival. In research on increasing food production, scientists are incorporating desirable traits from E 35-1 (the cultivar used in ICRISAT's research in Burkina Faso) into a locally adapted cultivar.

## Research Capabilities

Some of the SADCC countries have more advanced agricultural research programs then others.

Zambia, for example, has a long history of growing sorghum and pearl millet, though in recent years maize has become more important. ICRISAT's SPV 386 was released in 1983 as ZSV 1 and is being grown by a number of commercial and small-scale farmers. The national research program can manage crossing blocks, nurseries, and yield trials with little assistance in anything but introduction and preliminary evaluation.

Swaziland, on the other hand, has almost no research staff and will need assistance at nearly every stage as it establishes a research program.

Within the region, problems vary radically. Cold-tolerant cultivars are important for farmers in Lesotho, but not in Zambia, where acid soils are a serious problem. Shoot fly is a major pest in Tanzania but is not serious in Botswana.

The SADCC-ICRISAT staff is identifying locations where insect infestation or diseases are unusually heavy and will concentrate regional research efforts on these hot spots. Zimbabwe, for example, has a problem with stem borers but the best place for a screening program is at the Golden Valley Research Station in Zambia. Technicians from Zimbabwe will be sent there as in-service trainees to participate in screening work. Leaf diseases will be studied in central Zimbabwe, acid soil in northern Zambia, and work on drought stress will be carried out near Gaborone, Botswana. The regional approach gives SADCC-ICRISAT flexibility in coordinating research for the benefit of several countries at the same time.

Programs in the SADCC region need support of many kinds. Donor financing for the project now includes contributions from the Canadian International Development Agency (CIDA) and the West German Ministry of

*Scientists from the SADCC region evaluate promising sorghum lines in Dodoma, Tanzania.*

Economic Cooperation (BMZ), in addition to USAID. While supporting research and training activities, it also provides funds for supplying national programs with useful, low-cost items, such as pollinating bags, scissors, pruning shears, tweezers for breeding work, metal seed trays, field books, plastic bottles, and bird netting. ICRISAT provides instruction in use and maintenance of these supplies.

Facilities for postharvest management of crops are extremely poor in much of the area. Seed is lost from season to season, nullifying the value of previous research. The ICRISAT team is developing a basic technology package, including building design, storage, threshing, and cleaning facilities, to guide SADCC national scientists in setting up or improving their ability to store and maintain valuable material.

## Advanced Training

Training national scientists and technicians is one of the most important parts of the SADCC-ICRISAT program. Preliminary studies have identified requirements and outlined a 10-year phased program for each of the nine countries. The plan calls for 37 PhD and 26 MS degree programs in nine different disciplines: sorghum and millet breeding, agronomy, soil science and nutrition, physiology, pathology, entomology, food quality, and weed science.

The first trainee, a woman from Malawi, went to Texas A&M University for a PhD in entomology in July 1985, and sorghum breeders from Zambia and Zimbabwe left for the USA a few months later to study for MS and PhD degrees. INTSORMIL, a USAID collaborative program with American land-grant universities, handles arrangements for the educational program.

Scientists will begin training at different times so that all of them will not be away at the same time. In addition to university-level studies, plans call for training technicians at ICRISAT Center in India and at various stations in the SADCC countries. Technicians will be trained during the year that advanced-degree students are completing their work so that they will be ready to form an effective research team when the scientists return.

Project headquarters at Matopos will offer in-service training for periods of 2 weeks to 3 months, covering techniques such as studying disease and pest problems.

Looked at as a whole, the many parts of the SADCC-ICRISAT program offer a unified approach to agricultural research that can help meet the SADCC Heads of States' long-term goal of achieving food security in their region.

# Groundnut in Southern Africa: A One-Crop, Regional Program

Though it has been operating only since late 1982, ICRISAT's southern Africa regional groundnut program has established a vigorous cooperative research network among scientists in seven countries.

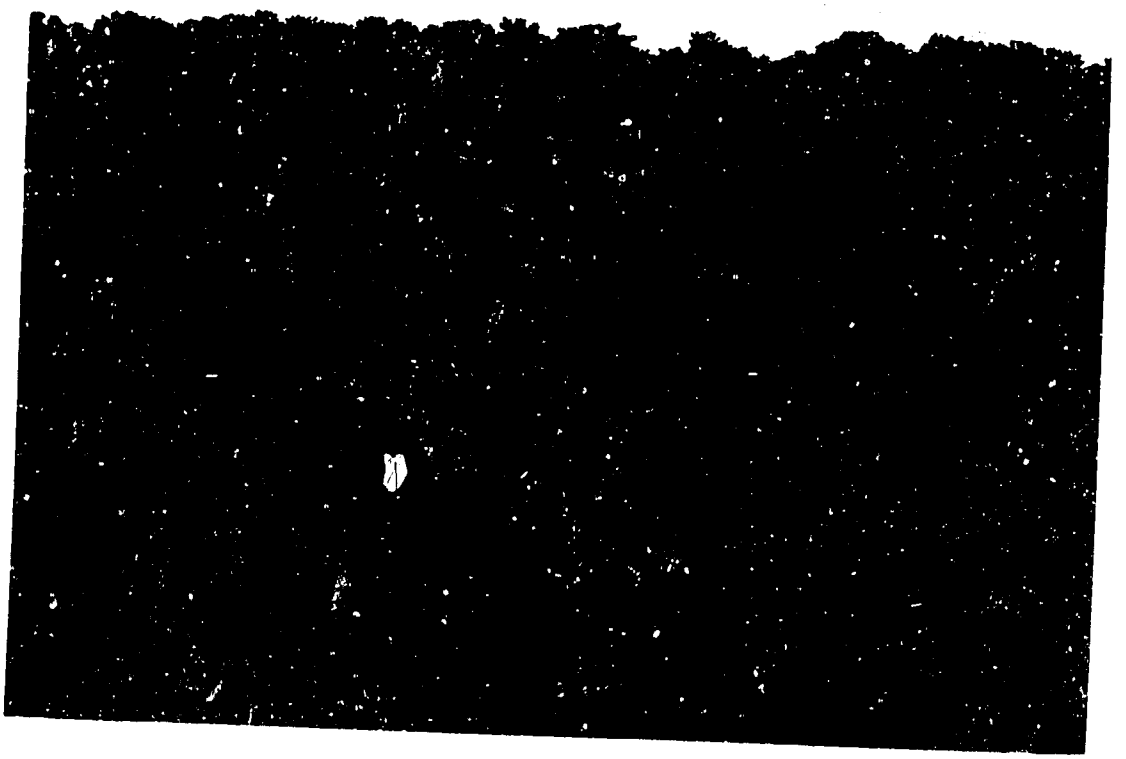
The primary aim is to broaden and enhance the genetic resources of groundnut in southern Africa by evaluating lines developed from ICRISAT's world collection in India, germplasm introduced from elsewhere in the world, and useful breeding lines from local national programs.

The regional program is also generating material from its own hybridization program by crossing high-yielding, exotic germplasm lines and locally adapted varieties and making specific crosses in response to special requests from national breeders.

From this introduced and generated genetic wealth, outstanding lines are identified on the basis of yield, quality, and resistance or tolerance to diseases. These are tested in regional trials (in close cooperation with national programs) to identify groundnut lines suited to the climates and agricultural conditions of the region.

Because the program's target group is the small-holder with limited financial resources

*New breeding material is generated at ICRISAT's regional groundnut program, based in Malawi, focused on the needs of the SADCC countries*



who cannot afford pesticides, herbicides, or irrigation, most research is on nonirrigated experimental fields with no crop protection. To insure reasonable plant growth, minimal amounts of phosphorus and gypsum are used.

The Canadian International Development Research Centre (IDRC) is providing more than $1 million over a 4-year period to finance the project, which has a two-man international staff.

The regional groundnut program is another ICRISAT response to a request for assistance in strengthening research from heads of State of the Southern Africa Development Coordination Conference (SADCC), and covers the same general area as the sorghum and millet program at Matopos, Zimbabwe.

The Government of Malawi originally provided facilities for the ICRISAT-IDRC program at its station at Chitedze, near Lilongwe. These have been replaced by expanded space on the Colby College campus nearby. The Malawi location is ideal for visits to national programs of Zambia, Botswana, Zimbabwe, Mozambique, Swaziland, and Tanzania.

Of the remaining SADCC countries, Lesotho is too cold for groundnut and there has been little contact with Angola until recently when the first sets of ICRISAT regional trials were sent to the Angolan capital, Luanda, at the request of FAO.

## Cooperative Research with National Scientists

This program relies on scientists from national programs to carry out regional trials and to select varieties.

In the 3 years it has been operating, regional trials have shown that several selections made by ICRISAT's breeder in Malawi significantly outyield the standard local varieties. These lines are of immediate value to national breeding programs and can also be used as varieties in their own right.

The program fosters close collaboration among groundnut researchers in the region, establishing a network of cooperating research programs, disseminating and sharing information through regional workshops and specialist group meetings, and by a regional newsletter. A specialist group tour for the region's breeders in 1985 included visits to breeding programs in the field in Zimbabwe, Zambia, and Malawi.

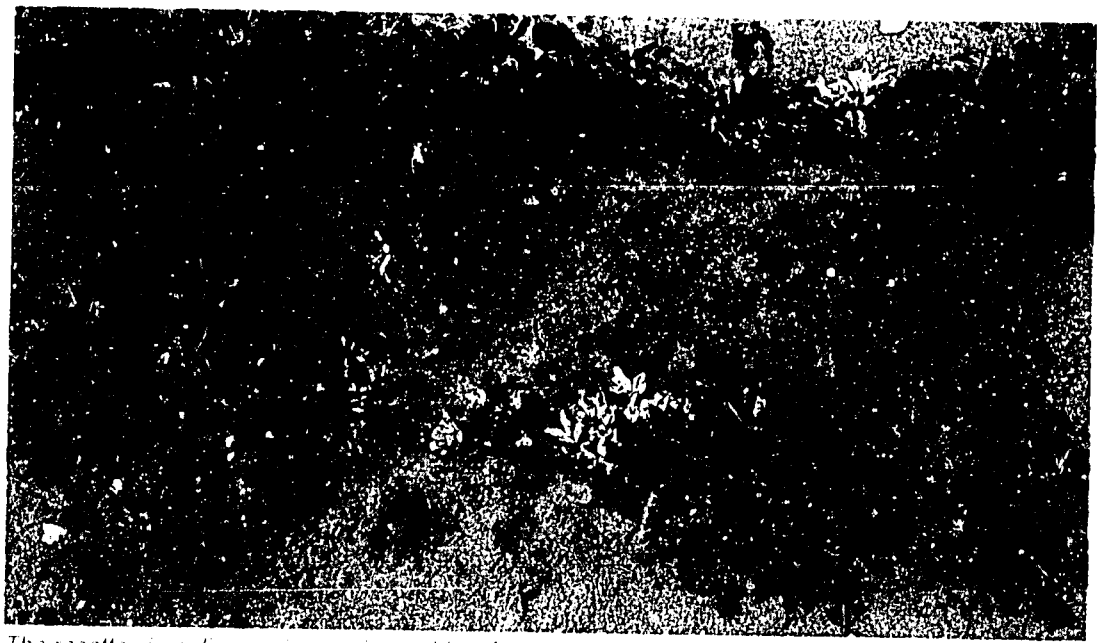
Although regional cooperative research is an important aspect of their work, the two ICRISAT scientists also carry out research on major problems at their base in Malawi, including aspects of resistance to, and epidemiology of, rosette disease, resistance to early leaf spot, and generation of new material by hybridization.

## Potential for Increase

Groundnut is both a cash and food crop in southern Africa, an area of about 4.9 million square km that ranges in altitude from sea level to more than 3500 m. Yields on small farms, where most groundnut is grown, are generally low, often much less than 1 tonne/ha. Large-scale farms with irrigation and plant protection get 4 tonnes/ha, and the record of 9.6 tonnes/ha was reported from a commercial farm in Zimbabwe.

The possibilities for increasing groundnut production in southern Africa are great, but progress has been slowed by a shortage of suitable varieties in some of the countries, limited seed availability, damage from diseases and insects, and uneven rainfall.

Rains in the major groundnut area begin in mid-November, are heavy in December, erratic in January, with breaks of 10 to 15 days, and heaviest in February. They dwindle in March, and in many areas there is no rain at all from April until November. In Malawi, nothing is in the ground during this



*The rosette virus disease is a major problem for groundnuts in Africa. ICRISAT's regional program in Malawi works on ways to reduce damage.*

dry period except for a few vegetable crops in moist, silted valleys.

Groundnut follows maize and tobacco in a rotation that serves to improve the soil after the tobacco because groundnut is not subject to infestation by the tobacco nematodes.

As a result of lagging official prices, farmers have shifted away from groundnut to maize, and groundnut production in southern Africa has fallen sharply. Once the third-largest export of Malawi, groundnut is now only a small percentage of its exports. Several countries in southern Africa have been forced to import groundnut oil in drought years.

Groundnut is eaten with maize or in sauces. It is sold boiled or roasted in the market, and the leaves are sometimes used in cooking. In Mozambique, farm families cook groundnut with cereals to increase the nutritional value (especially for children) of the cereal carbohydrate.

Groundnut is not native to Africa, and virtually all improvements in production have been based on introduced germplasm. ICRISAT holds a world mandate for research in groundnut, and its gene bank in India contains more than 13 000 accessions from all over the world.

## Diverse Area

Because the area covered by the southern African ICRISAT groundnut program is so diverse, it might be well to look briefly at programs in each country.

Malawi has done breeding work for well over three decades. Approximately 75% of its groundnut production is on the Lilongwe plain. The country is relatively strong in trained research personnel, but nearly all suitable land is cultivated during the growing season, so increasing yields per hectare is a major goal.

Malawi's Chalimbana is a large-seeded confectionery variety much in demand in the Netherlands and United Kingdom, but it is highly susceptible to disease. Increasing the

yield of Chalimbana is a problem because it has proved difficult to select higher-yielding strains that retain the tan color, good flavor, and the extra-large size consumers prefer. Recently, however, Malawi breeders have met with some success and they will shortly release an improved Chalimbana.

Botswana was traditionally cattle-raising country, but as the people have become more sedentary, groundnut cultivation has increased. The current production of 1200 tonnes provides only one-third of its needs. With rainfall at about 300 mm annually, drought tolerance is the prime requirement for groundnut here, so ICRISAT's drought-resistant material is being tested for yield.

Zimbabwe has four commercial centers for groundnut cultivation on high-potential land with irrigation, but developing suitable varieties for farmers on communal lands—where groundnut is a low-yielding sole crop—has been neglected. Both long- and short-duration varieties, stable over a wide range of environments, are being developed, with emphasis on finding suitable oilseed.

Zambia is developing a strong groundnut improvement program aimed at helping small farmers increase yields under traditional management and is using ICRISAT groundnut lines. It hopes to achieve self-sufficiency in oilseed production and develop an export trade in confectionery nuts. High-yielding varieties resistant to leaf spot, rust, and rosette virus are needed.

Tanzania, where groundnut is widely grown in central areas, is desperately short of funds for running trials. Tests of Robut 33-1, introduced from ICRISAT Center's collection, were very encouraging, with significant yield increases that make it an ideal variety for peasant farmers.

Mozambique has no trained breeders, and ICRISAT is helping it organize research and is providing some supplies, including fungicides for research at the University of Maputo. Farmers generally grow landrace varieties, and in some areas groundnut is second only to cereals in importance.

Swaziland's program is very small. Some groundnut is grown in the east, but it has not yet become an important crop.

## Disease and Insect Problems

Disease and insect problems of groundnut in the region vary in degree of severity from country to country and within countries, and groundnut pathologists and entomologists are in very short supply. Diseases of outstanding importance in most countries are early leaf spot and rosette virus disease.

Rust disease is serious in the hotter, more humid, lower lying areas in southern Mozambique and parts of Tanzania and Malawi. Another foliar disease, *Phoma* is found in Zimbabwe. ICRISAT breeders will cooperate with Zimbabwe scientists to incorporate *Phoma* resistance of lines from the USA and Zimbabwe into agronomically acceptable cultivars.

Host resistance is particularly important in a region where many farmers are not used to knapsack sprayers, and where sources of water supply may be far from the fields. Breeding and selecting for resistance to early leaf spot and incorporating known resistance to rosette disease into high-quality varieties are therefore critical research areas for the ICRISAT program and for several national programs in the SADCC region.

Termites are a major pest throughout the region, especially in dry years. They destroy pods and sometimes the entire groundnut plant. Control is too expensive for most peasant farmers.

*Hilda patruelis*, a sucking bug is devastating to groundnut crops in some locations in Africa. It thrives in association with colonies of small black ants. Attacks are sporadic, and damage can range from one or two plants in a field to 90% loss. Adding an inexpensive insecticide to the soil before sowing to control the ants or treating early plant

infestations with a spray seem to be the best strategy to deal with this problem.

## The Mystery of Rosette Virus

The rosette virus study that ICRISAT recently started is a good example of the tremendous value of a regional approach to disease problems.

The virus is found only in Africa and is second to leaf spot as a major threat to groundnut production. Epidemics of devastating proportions are sporadic, but when they occur can cause almost 100% loss of crops planted late and at wide spacing. The virus has not been a problem during drought years, but now that rains seem to be returning, it is expected to become serious again, causing fields of groundnut to turn bright yellow with great loss of yield.

Rosette virus is spread among plants by aphids, and it appears that two viruses are involved. No one knows where the infected aphids come from each season.

It is essential to learn more about the ecology of the aphids so scientists can develop strategies for control. This complex multidisciplinary puzzle brings together the fields of botany, meteorology, virology, and entomology and crosses all national boundaries.

Rosette virus is a serious problem in West Africa as well, so when ICRISAT's southern African program sheds light on rosette ecology, its work should be of value to such countries as Senegal, Nigeria, and Gambia. ICRISAT Center has been instrumental in enlisting a group of scientists from the Federal Republic of Germany, the United Kingdom, the USA, and Nigeria to collaborate on finding the solution to various aspects of the menace of rosette.

## Training Opportunities

ICRISAT's regional groundnut program does no formal on-station training. It helps as many technicians as possible from southern Africa study at ICRISAT Center, with the aim that a number of technicians from each country will benefit from training there. The program also acts as a clearing house for other training opportunities both in and outside the region.

Building a good support staff for national programs depends on this training, which fits in well with the off-season in southern Africa, since technicians leave for ICRISAT Center after the harvest in May and are back in time for planting 6 months later.

## Signal of Commitment

As a signal of ICRISAT's increasing commitments to research in the southern African region, in cooperation with countries of the SADCC, the ICRISAT Governing Board met in Harare, Zimbabwe, during March 1986. Several scientists and science administrators from the region took active part in the deliberations.

The Board members were quite impressed by what they saw and heard during visits to research farms in Malawi, Zambia, and Zimbabwe and felt that the work initiated there has a good potential to address the problems of the entire region. They suggested that ICRISAT researchers pay greater attention to alternative uses of sorghum and millet, including the possibility of mixing flour from these grains with wheat flour in breadmaking. Training in research-station management was also emphasized, to speed up transfer of technology.

# Eastern Africa: A SAFGRAD-ICRISAT Initiative

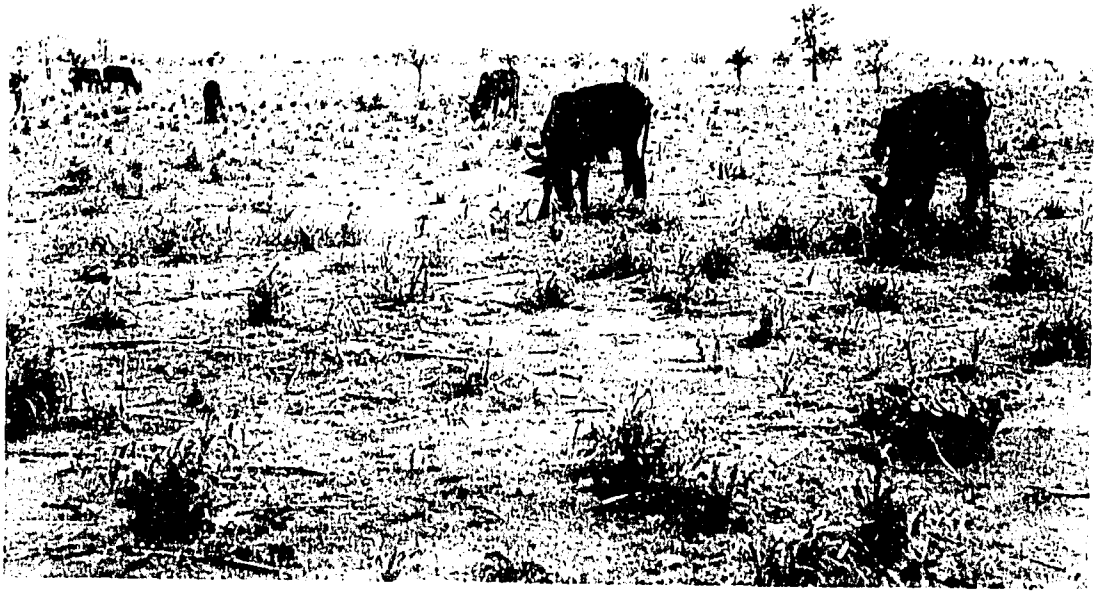
Sorghum is one of the most important crops in eastern Africa. In many places if sorghum fails, people starve. Sorghum is generally raised on farms of less than 2 hectares by the poorest farmers.

ICRISAT's Eastern Africa Regional Sorghum and Millet Project is dedicated to helping national scientists generate technologies that will increase yields and stabilize production of these cereals, which have the best chances of survival in times of drought.

The only way to improve the lot of each country is through national programs, the leader of this program believes. "You can have a miracle variety, but as long as things are not going well at the national program level, nothing will happen," he says. He emphasizes the necessity of motivating national scientists to develop improved cultivars and carry new technologies to the farmer.

The program headquarters are in Nairobi, Kenya. It is part of the Semi-Arid Food Grains Research and Development (SAFGRAD) Project of the Organization of African Unity (OAU), and is largely financed by USAID. No independent research is now carried out by the project, which works directly with scient-

*Severe drought spells leave the farms patchy and animals hungry, forcing farmers to let the animals graze on what is left of their crop.*



*Even during good years, crop and livestock rearing activities are closely related in most of Africa.*

ists in national agricultural programs and has a coordinating role, but eventually there will also be a research-based program.

Participating countries are Sudan, Ethiopia, Somalia, Kenya, Uganda, Rwanda, Burundi, and Tanzania. Although not part of the African continent, the Peoples Democratic Republic of Yemen and the Yemen Arab Republic are also included because their agricultural conditions and practices are similar to those in eastern Africa.

## East-West Contrast

Why two SAFGRAD-ICRISAT initiatives in Africa, one in the East and one in the West? Isn't an Africa-wide strategy possible? Several major contrasts stand out.

Soils in West Africa are sandy and rainfall is poor; soils in eastern Africa are better, with more organic matter, clay, and better water-holding capacity. As a result, the potential for increasing yields per hectare and increasing the area under cultivation is probably greater in eastern Africa, though it has suffered from disastrous drought and famines in recent years.

Altitude, however, is the major modifying factor. In eastern Africa, sorghum is grown from sea level to more than 2300 m. High and intermediate elevations generally have good rains, lowlands may be either wet or dry. Moisture is not ordinarily as much a limiting factor as it is in semi-arid West Africa, and cultivars must be developed for growing seasons of varying lengths. The ICRISAT program has identified four adaptation zones: high, intermediate, and low elevations, and very dry lowlands. Varieties are tested in each of the four zones.

Sorghum has been grown in Africa for thousands of years, and species native to

the east have differently shaped panicles (flower clusters) and kernels from those of West Africa, though over time there has been some intermixture. West African farmers grow pearl millet; in eastern Africa, finger millet is preferred. Because the ratio of land in sorghum to that in millet is about 9:1, the ICRISAT program currently concentrates on sorghum.

Improved varieties developed at ICRISAT Center that grow well on the Indian subcontinent have transferred well to Ethiopia and contributed to food production there.

## Regional Trials

A regional sorghum workshop in Ethiopia in 1982 developed plans for Eastern Africa Cooperative Sorghum Regional Trials, and these continue, using uniform guidelines from ICRISAT for recording data. Millets were added to the program in 1983, and results of millet national trials are discussed in the annual workshops.

The sorghum trials have proved to be a good avenue for intercountry cooperation, leading to rapid movement of germplasm, technical information, and research techniques. The Nairobi-based SAFGRAD-ICRISAT coordinator visits each country every year to evaluate the trials with national cooperators.

For the first trials in 1983, seven countries sent 43 varieties for the four sets of regional trials. Each country sent 2 to 3 kg of seed for the trials to the coordinator in Nairobi, who distributed seed packets to 50 locations for testing.

Entries give a picture of the variations in the region: material from Uganda and Tanzania was only for elevations under 1500 m; Burundi and Rwanda, which had varieties for high and intermediate areas, had no entries for dry lowlands.

The Yemen Arab Republic, Ethiopia, and Kenya offered varieties suited to all four adaptation zones. Two of the entries for low elevations were ICRISAT-bred and released: Ethiopia's Melkamash 79 and the Yemen Arab Republic's Sepon 80-1. The 1985 regional trials included 47 entries from 10 countries to be tested on national research stations in 40 locations in the different ecological zones.

Outstanding varieties from the tests can be identified by national programs and used for further testing and production or as parents in breeding work. After the initial trials, several countries indicated they planned to work with tested varieties (including Melkamash 79 and Sepon 80-1) from other countries.

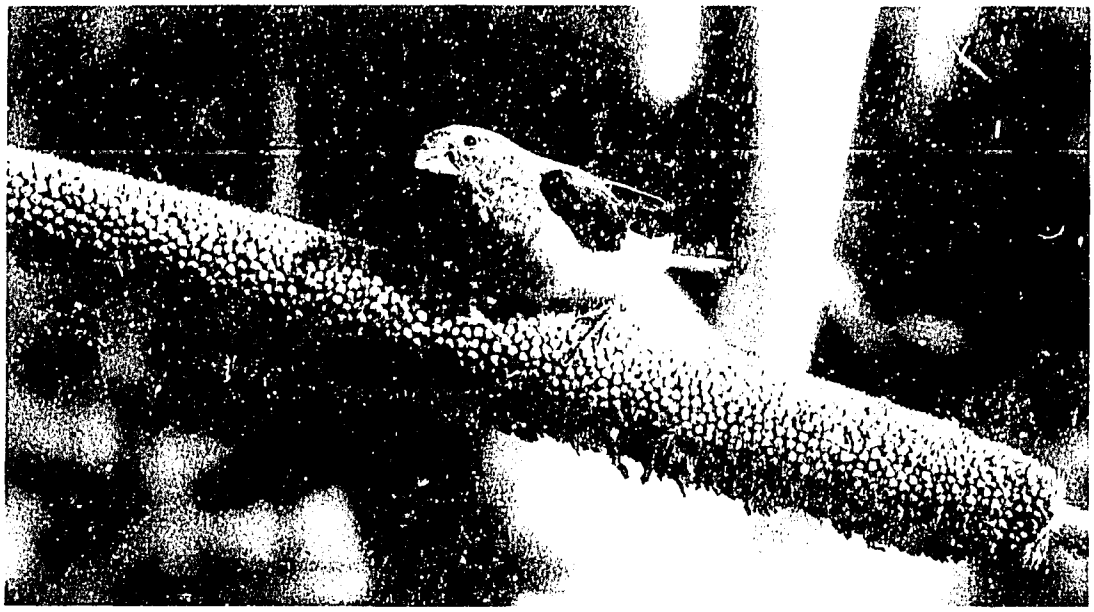
Results of the sorghum trials have shown that varieties can be transferred within the same ecological zone and that a regional breeding program can develop varieties suitable for a number of countries.

SAFGRAD-ICRISAT has also assisted national scientists in establishing an Eastern Africa Cooperative Screening Nursery. It started with more than 1000 seed sources from Ethiopia, Tanzania, Uganda, ICRISAT/SAFGRAD Kenya, and ICRISAT Center, and will eventually be narrowed down to about 200 selections for testing in all the countries of the region.

National scientists discuss the results of regional trials and nurseries at the annual workshops, which have been held since 1982 in Ethiopia, Rwanda, Tanzania, and Uganda. Workshops focus on research efforts in the host country, with brief reports from each national program and invited papers on problems of special interest.

These events offer researchers a chance for peer review and foster a sense of fraternity among the scientists, who formerly worked in relative isolation. Each country benefits from the work of its neighbor; researchers from countries that do not speak to one another on the political level cooperate in searching for strategies to increase food production.

In addition to regional trials, several national programs in eastern Africa have taken part in multilocational tests and insect and disease



*Birds, too, are a hazard to food production throughout Africa. They attack the crop and eat the grain, as on this millet head.*

nurseries sponsored by ICRISAT. Uganda participated in the International Sorghum Shoot Fly Nursery; Uganda and Ethiopia in the International Sorghum Downy Mildew Nursery; and a leaf disease nursery was tested at two locations in Sudan.

## Desired Qualities

Desired qualities in sorghum in eastern Africa vary from country to country. Drought tolerance is always at the top of the list, and high yield is only one of many considerations.

In times of plenty, when people have some choice, each society has specific preferences. In times of starvation, as in recent years, people will eat almost any variety of sorghum, whether they like it or not.

In Ethiopia, where sorghum is used alone or in conjunction with *tef*, a local cereal, to make traditional fermented bread called *injera*, the demand is for pearly white sorghum. In Uganda, Burundi, and Rwanda, brown-seeded sorghum with a high tannin content is most common and is considered acceptable for making *ugali* (a thick porridge), opaque beer, and a nonalcoholic, high-calorie drink for children.

In eastern Kenya, sorghum with pearly white grains that look like maize is preferred; in the west, a brown, high-tannin variety is acceptable for making *ugali*. Grain with hard endosperm is preferred in much of Tanzania. National programs must develop lines that meet local demand, and since ICRISAT Center has the world collection of sorghum germplasm at its gene bank in India, it is the richest possible source for breeding material.

The different climates in eastern Africa call for different types of sorghum. A quick look at the findings of the regional trials points up some differences.

In high altitudes, farmers prefer varieties that are late blooming and tall. But the tall, late-blooming, large-seeded Yemeni varieties that reported highest yields (around 3000 kg/ha) were considered agronomically undesirable in a test location in Kenya, while high-altitude Rwanda sorghums with deep

brown seeds were not well adapted to the Yemen sorghum environment.

Trials in very dry lowlands had a "high probability of failure," a summary report showed, and yields were very low, with most varieties showing undesirable agronomic traits. Varieties for this most difficult sorghum production area will require a great deal of improvement.

## Pests and Weeds

While high-tannin, brown-seeded varieties are not generally preferred, they have one quality that is highly desired—they are not attractive to the tiny, red-beaked *Quelea* birds that descend by the hundreds of thousands on growing fields and demolish the crop. As a result, brown-seeded sorghum is being grown increasingly despite the fact that people often don't care for its slightly bitter flavor.

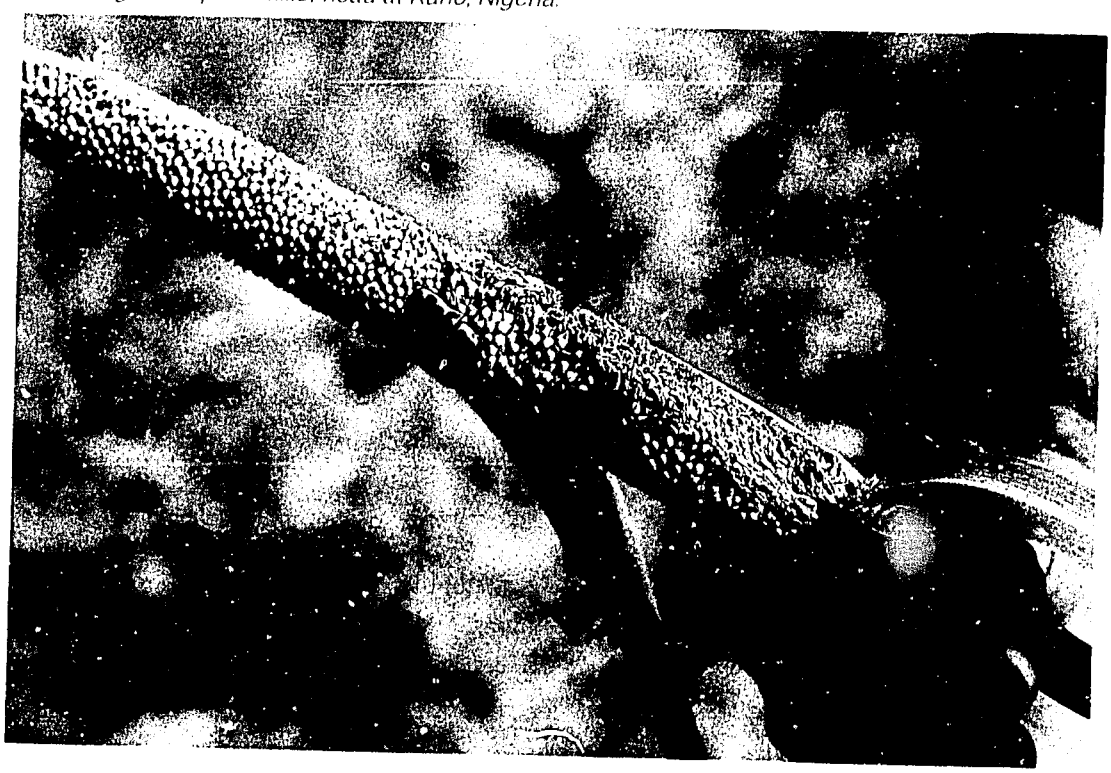
How farmers can deal with the *Quelea* problem was on the agenda for the SAFGRAD-ICRISAT regional workshop in Uganda in 1985 and is also a major concern of the SADCC-ICRISAT program in Zimbabwe.

Armyworm, like *Quelea*, is migratory and appears in vast numbers when environmental conditions are right, wiping out sorghum crops and almost any other plants in the field. Host resistance is unknown, and research on this pest is urgently needed.

*Striga*, a serious hazard to sorghum in West Africa, is also common throughout eastern Africa. In Tanzania, for example, two types of *Striga* cause serious crop losses and limit expansion of sorghum cultivation.

Ethiopia and Sudan are carrying out long-term studies of the parasitic weed, and Kenya at one time achieved some reduction

*Head bugs on a pearl millet head at Kano, Nigeria.*



*Insect damage is quite common on crops in all of Africa. ICRISAT scientists adopt an integrated approach to try and reduce crop loss from insects.*

in *Striga* levels by demanding that farmers pull it up. Host-plant resistance is the best prevention, and eastern African national programs are following results from ICRISAT work in West Africa and India on developing resistant strains.

## Cropping Systems

Where there are two rainy seasons, farmers generally do not plant the same crop twice; they are more likely to plant a legume, followed by a cereal, which may be maize one season, sorghum the next.

One practice some farmers use is to broadcast a mixture of seed at random—sorghum, beans, maize, for example. If rains are good, there will be food for the family over an extended time. If rains do not hold up, the sorghum is most drought resistant and is the last to be harvested. The beans fix nitrogen in the soil and add to its fertility, and the scheme minimizes insect damage because the same pests don't attack all of the crops.

## Providing Literature

Current scientific literature is hard for sorghum and millet researchers in eastern Africa to get, and they have increasingly turned to ICRISAT for literature searches and reprints. Proceedings of the annual workshops, sponsored jointly by IDRC and SAFGRAD-ICRISAT from 1982 to 1984, have been distributed throughout the region, as has the Sorghum and Millet Information Center (SMIC) newsletter, published three times a year from ICRISAT Center.

Experts from ICRISAT are frequently called upon for advice or for short-term consultancies in areas of concern to national scientists.

## Building Up National Research

To improve the future of eastern African agriculture, one of ICRISAT's greatest contributions will be through training national program scientists and technicians. The SAFGRAD-ICRISAT office in Nairobi helps national programs identify promising candidates for training. During 1985, 25 persons from eastern African countries participated in in-service training at ICRISAT Center in India, and three Somalis and one Ethiopian continued there as research scholars in 1986.

# Looking Ahead

This, then, is the story of ICRISAT in Africa in the mid-1980s. It is only the beginning of a long-term effort to make that continent, so rich in other resources, more self-sufficient in food.

ICRISAT scientists are aware that no matter how effective and productive the crop lines and farming systems they develop, there probably won't be a Green Revolution in the conventional sense in Africa. The harsh environmental conditions and the lack of resources available to struggling new governments to build a strong research base militate against that.

But they also know, from 10 years' experience in Africa and 13 in India, that the technology ICRISAT is developing can avert disaster and eliminate food shortages only if it is implemented by farmers and strongly supported by national governments and the world community.

ICRISAT can catalyze technological change through national scientists and organizations, but it is they who must bring about the agricultural transformation that will eventually take place in Africa. The process has begun. With the active participation of national and regional programs, it will be effectively carried forward.

*A well-managed field of the high-yielding pearl millet, CIVT, at the ICRISAT Sahelian Center, Niger, shows the potential of research to boost crop production in the region.*

*Two grain market scenes in Niger. In many parts of Africa, with its large share of subsistence farmers, not much grain gets to the market. Market studies are part of ICRISAT's socioeconomic research.*

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International Fertilizer Development Center (IFDC), USA

International Institute of Tropical Agriculture (IITA), Nigeria

International Livestock Center for Africa (ILCA), Ethiopia

Institut Français de Recherche Scientifique pour le Développement en Cooperation (ORSTOM), France

Organization of African Unity, Scientific and Technical Research Commission: Semi-Arid Food Grains Research and Development (OAU/STRC/SAFGRAD), Burkina Faso

Texas A&M University, USA

United Nations Development Programme (UNDP)

United States Agency for International Development (USAID)

University of Hohenheim, West Germany

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* Includes institutions sponsoring special projects, those deputing scientists to work on collaborative projects, and those offering use of their research facilities. The national research systems of many African countries are also involved, and they are not being listed separately.