ICRISAT Report 1992

ICRISAT
Report 1992

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

1993

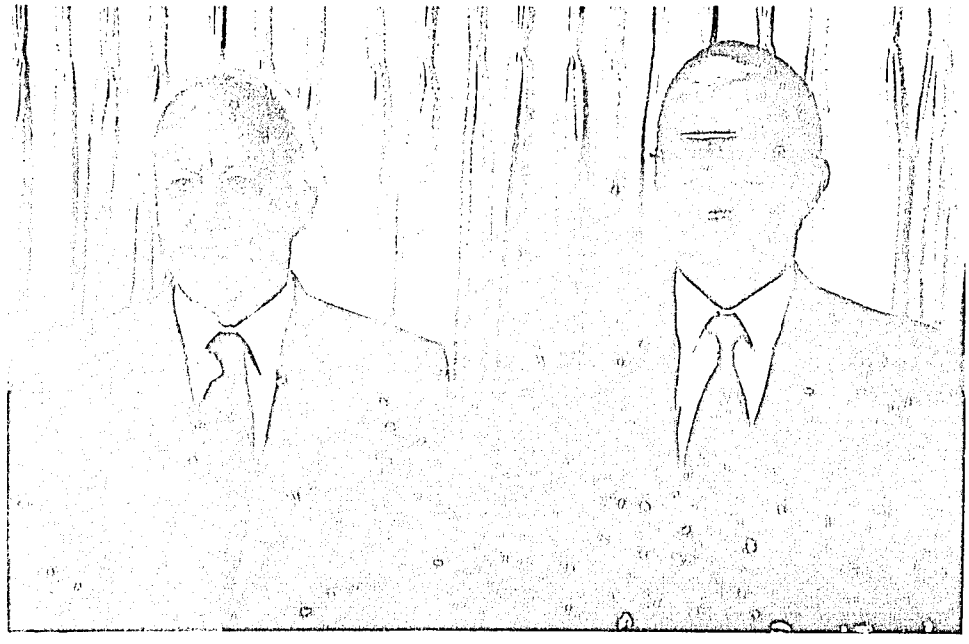
Cover photograph: *A farmer in Burkina Faso tending his sorghum crop.*
Inside cover: *Photomontage of some of the ICRISAT support staff at work.*

A

ICRISAT's Mandate

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

Report from the Chairman and Director General



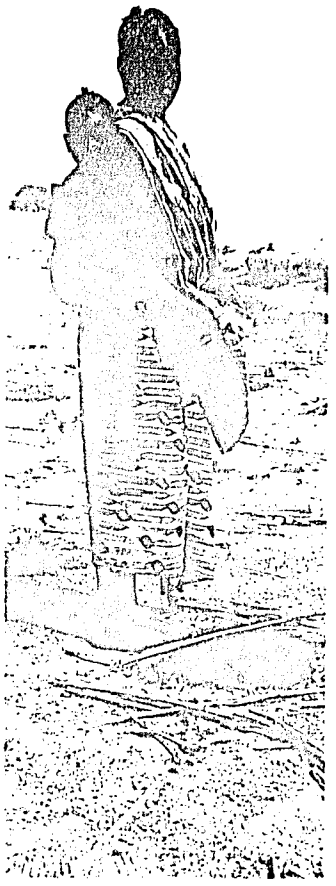
1992 was a significant year for ICRISAT. Our 20th Anniversary was celebrated in many ways at many locations, and in the process we looked back and took stock of ICRISAT's past achievements. However, 1992 was also a year in which we gave much attention to looking forward. An innovative and analytic process was used, involving all of the Institute's scientists, to develop a Medium Term Plan for the Institute's activities to 1998. At the same time, we continued with our ongoing research, and we continued to communicate with those for whose benefit our research is targeted.

The celebrations of the 20th Anniversary took several forms. At ICRISAT Center the foyer received a facelift, 50 posters were produced and a photographic record of the Institute's history was mounted and displayed. Children of our staff throughout the SAT painted wonderful pictures, and the festivities 'went to our heads' in bright yellow caps. We published a record of our first 20 years in English and French and included it as a supplement to our 1991 ICRISAT Report. On a more serious note we held a Panel Discussion on 'Sustainability and the environment in the semi-arid tropics: food production in the future' moderated by our new Governing Board Chairman, Professor Eric Roberts. The highlight of the celebrations was the visit of the Prime Minister of India, His Excellency P V Narasimha Rao. Paying a return visit—he was present when our foundation stone was laid in January 1975—the Prime Minister extended the full support and cooperation of the Government of India to ICRISAT.

The ICRISAT Sahelian Center, in Niamey, Niger, celebrated the 20th Anniversary with three open houses: for government officials, sponsors, donors, and diplomats, including Niger's Minister for communication Mr Albert Wright; for the general public; and for farmers.

At the SADC/ICRISAT facilities at Matopos, Zimbabwe, the occasion was celebrated by a visit from the Minister for Lands, Agriculture, and Water Development,

Report from the Chairman and Director General



Sahelian farmer.

Mr Kunbirai Kangai, who opened an Early Childhood Center built by ICRISAT for the Matopos community. He was presented with a check for Zim$ 11 350, contributed by ICRISAT staff members, as well as 330 20-kg bags of sorghum, millet,and maize harvested from ICRISAT experiments for Zimbabwe's National Drought Relief Fund.

The Anniversary was also celebrated by ICRISAT staff working in Mali, Mexico, and Nigeria. Speaking at the celebration in Kenya, Dr W.N. Masiga, of the Organization for African Unity, stressed the importance of ICRISAT's presence in Kenya and the confidence it generates amongst Kenya's national scientists.

This year saw several changes in our management team and in the membership of our Governing Board, and there was a particular note of sadness as we said goodbye to Bill Mashler, who retired from the Chairmanship of the Governing Board in March. His energetic service as a Member of the Governing Board since 1985, and as its Chairman since 1989, has characterized his long relationship with ICRISAT. Bill's enthusiasm has a way of rubbing off on all around him. Never satisfied with whatever we managed to achieve, he exhorted us to do more. To quote from his farewell speech. "While we have justifiable reason to be proud, we should look ahead and address ourselves to the future. We cannot tolerate hunger in our midst when the means are available for its elimination."

Bill left us with a fitting memorial. He presented the Institute with a gift—the Doreen Margaret Mashler Distinguished Scientific Achievement Award, an endowment in memory of his wife. Its purpose is 'to provide recognition of outstanding scientific achievements in the biological or social sciences contributing to ICRISAT's mandate, to encourage scientific excellence among the research staff, to reward creative scientific endeavor, and to create a perpetual memorial'.

It is to the Institute's credit that it can rise to the occasion when there is a crisis. The extreme drought that hit southern Africa presented a real challenge. Our scientists met this challenge with some highly appropriate responses, from rescuing endangered genetic resources, to providing emergency relief to the hungry, and producing vital seed material in the dry season to help the region's farmers start again once the rains came.

ICRISAT recognizes a requirement to assess the impact of our work to guide the direction of our activities, to evaluate the results of our programs, and to enable us to be fully accountable to our donors. New priorities for our economists reflect this, and their findings will be integrated into our future research strategies.

ICRISAT's Governing Board, at its meeting in March, ratified the merger of two networks; the Asian Grain Legumes Network and the Cooperative Cereals Research Network to form the Cereals and Legumes Asia Network (CLAN). The two former networks provided assistance to national programs in Asia in the exchange of germ-

plasm, breeding material, information and technology, and also in training technicians and scientists. When administrators of these national programs indicated their preference for working with a single network for all ICRISAT mandate crops, CLAN was created.

Recognition of the role played by women in agricultural development is growing, and ICRISAT is not alone in starting programs that will better respond to the needs of women, and to their place in the evolution and adoption of relevant technologies. In September, ICRISAT held its first Women Farmers' Day. The event was an unqualified success. It unquestionably made an impact on these important, frequently neglected, agricultural decision makers. But the impact of these farmers on ICRISAT was equally important. Their probing questions and unhesitating response to our scientists' queries will help us define the nature and direction of future research projects.

Our research efforts are not conducted in isolation—indeed they would not be possible without the continued effort of our many collaborators, from the national programs, universities, mentor institutions, sister CG Centers, and the private sector. This year's sorghum and millet field day at ICRISAT Center was specifically planned for private and public sector seed producers. We recognise the vital role they play in ensuring that the products of our research reach the farmers; equally, we appreciate the feedback they can provide by telling our scientists their perceptions of what the farmers really want.

The increasing competence of national programs, and the better defined needs of farmers are reflected in the changes in our breeding programs as exemplified by our work on pearl millet in Rajasthan. It was opportune that many members of our Governing Board were able to stay in India after the 20th Anniversary celebrations to join our collaborators on a visit to Rajasthan. There they met farmers and heard first hand of ICRISAT's efforts to develop pearl millet cultivars tailored to the needs of that particularly arid region.

Working together in Rajasthan.

The Asian Development Bank financed a collaborative project with the Department of Agriculture in Sri Lanka to promote pigeonpea cultivation in the dry areas of that country. We were equally pleased that the African Development Bank is funding a new project to promote wider cultivation and use of pigeonpea in eastern and southern Africa. This demonstrates considerable interest in pigeonpea, and we look forward to pigeonpea's contribution to sustainable dryland agriculture with the welcome involvement of national programs.

Report from the Chairman and Director General

The increasing capabilities of the national programs are well demonstrated by the handing over in November to Zimbabwe of all the forage breeding material relating to research conducted at the SADC/ICRISAT Sorghum and Millets Improvement Program since 1987 to the Government of Zimbabwe. The material included sorghum, pearl millet, legumes, grasses, and browse species. Dr Tim Smith, Head of the Matopos Research Station, Department of Research and Specialist Services, in accepting the material affirmed that the work begun by the SADC/ICRISAT staff will be carried on with the same enthusiasm by Zimbabwean scientists.

At the other end of the scale we proved our ability to help an emerging national program by starting a project to build an effective research and extension system in northern Namibia. A functional breeding program for pearl millet and sorghum has already been established and about 60 tons of seed of pearl millet Okashana 1 were produced in 1992—enough to benefit 30 000 Namibian farmers.

Net core funding in 1992 amounted to US$ 27.3 million. This represented a decrease of 7.3% from 1991 and led to significant reductions in staff and operations. Indications from the CGIAR are that 1993 core funding will be reduced from that for 1992. Despite this reduction in funding several new programs were started, and many established programs regained impetus with a change in emphasis. Notwithstanding the retrospection engendered by our 20th Anniversary events, 1992 was essentially a year in which we prepared ourselves to become more effective in a changing future environment. We laid the groundwork for more multidisciplinary approaches to address the complex problems besetting the search for genuinely sustainable agricultural growth throughout the marginal lands of the semi-arid tropics. The entire Institute contributed to the development of an optimum portfolio of research themes identified in our Medium Term Plan. We are most grateful for the past support of our donors and sponsors: our future impact is dependant on their continued support to the extent indicated in our Plan.

E H Roberts
Chairman, Governing Board

J G Ryan
Director General

ICRISAT Governing Board 1992

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M S Gill, *India* (from August)
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K V Natarajan, *India* (until June)
Chief Secretary to the Government of Andhra Pradesh
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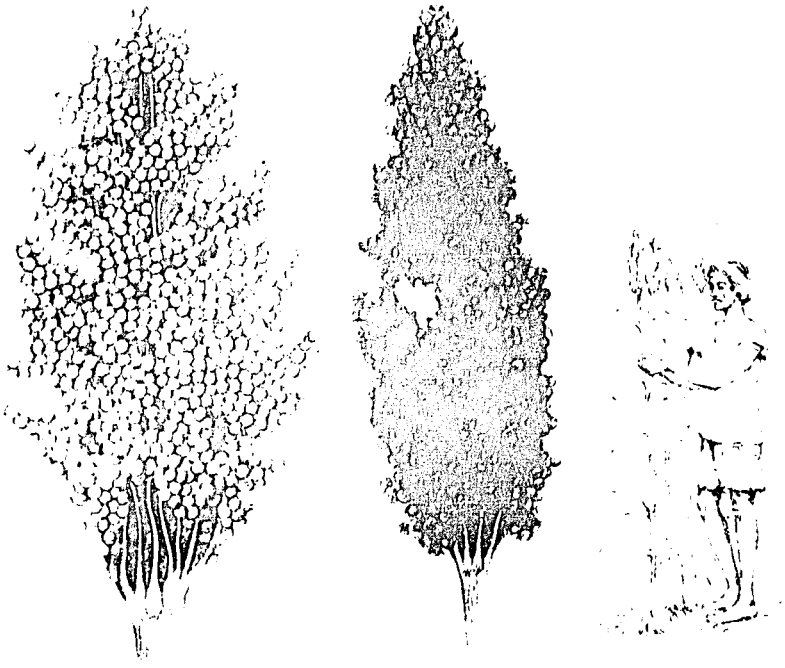
ICRISAT's Crops

Sorghum

Sorghum bicolor (L.) Moench

Sorghum is a major staple in the diets of the people of the semi-arid tropics (SAT), it is grown on over 40 million hectares, and is a hardy and dependable crop that grows well under adverse conditions. Sorghum grain is also used to feed livestock and poultry, particularly in the Americas. Its stalks provide fodder, fuel, sugar syrup, and building materials. ICRISAT works on sorghum at ICRISAT Center, WASIP-Mali and Nigeria, EARCAL, SADC/ICRISAT SMIP, and LASIP.



Pearl Millet

Pennisetum glaucum (L.) R.Br

The most widely cultivated millet in the SAT, pear millet is grown on an estimated 25 million hectares. It is adapted to dry regions and sandy infertile soils where rainfall is low and erratic, and can be successfully cultivated in areas too dry for sorghum. The grain is used to make unleavened breads on the Indian subcontinent and gruel, dumplings, couscous, or beer in Africa. Pear millet is a good source of fresh and dried fodder for livestock. ICRISAT works on pearl millet at ICRISAT Center, ICRISAT Sahelian Center, EARCAL, and SADC/ICRISAT SMIP.

Finger Millet

Eleusine coracana (L.) Gaertn.

Finger millet in grown in Africa and India in areas with 900-1200 mm annual rainfall. It is rich in calcium and iron, and is a basic food crop in the highlands of eastern and southern Africa. ICRISAT works on finger millet at SADC/ICRISAT SMIP and EARCAL.

Chickpea

Cicer arietinum L.

Chickpea is the primary pulse crop in South Asia where it is an important source of protein, particularly in vegetarian diets. The grain and haulms are used to feed livestock. Chickpea cultivation is expanding due to the development of cold-tolerant, disease-resistant genotypes. ICRISAT works on chickpea at ICRISAT Center, and with ICARDA in the West Asia North Africa (WANA) region.

Pigeonpea

Cajanus cajan (L.) Millsp.

Pigeonpea, like chickpea, is predominantly a crop of South Asia. Its significance as a pulse crop is increasing in the Caribbean and eastern Africa. It is used as a dried pulse cooked and eaten in many forms, and as a fresh, green, protein-rich vegetable. Pigeonpea also provides forage, green manure, and fuelwood. ICRISAT works on pigeonpea at ICRISAT Center, EARCAL, and in special projects based in Malawi and Sri Lanka.

Groundnut

Arachis hypogaea L.

Groundnut is widely grown between latitudes 40° N and 40° S and is the most important oilseed of the SAT. It provides a high-quality cooking oil, a wide range of confectionery products, and is a major source of protein for both humans and animals. The haulms are fed to livestock, especially in the drier parts of the SAT. Groundnut is a cash crop for many resource-poor farmers; it also provides much-needed foreign exchange to semi-arid tropical countries when sold in the international market. ICRISAT works on groundnut at ICRISAT Center, ICRISAT Sahelian Center, and the SADC/ICRISAT Groundnut Project.

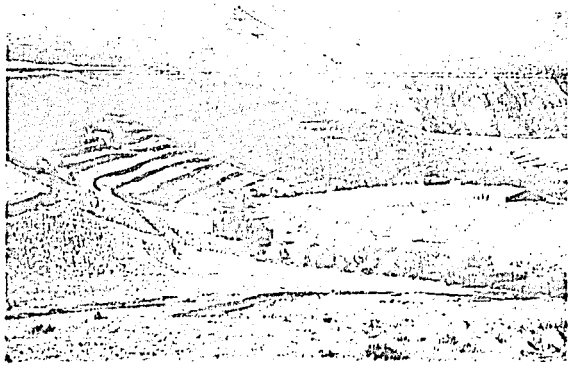
ICRISAT's Locations

Latin American Sorghum Improvement Program (LASIP)

ICRISAT Sahelian Center (ISC) Nige

West African Sorghum Improvement Program (WASIP) Mali

West African Sorghum Improvement Program (WASIP) Nigeria



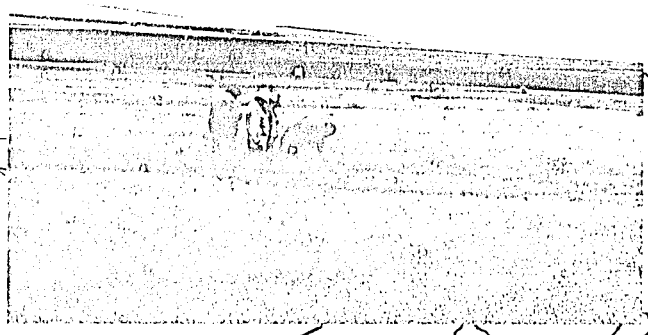
Namibia/ICRISAT Bilateral Project Namibia

SADC/ICRISAT Sorghum and Millets Improvement Program (SMIP) Zimbabwe

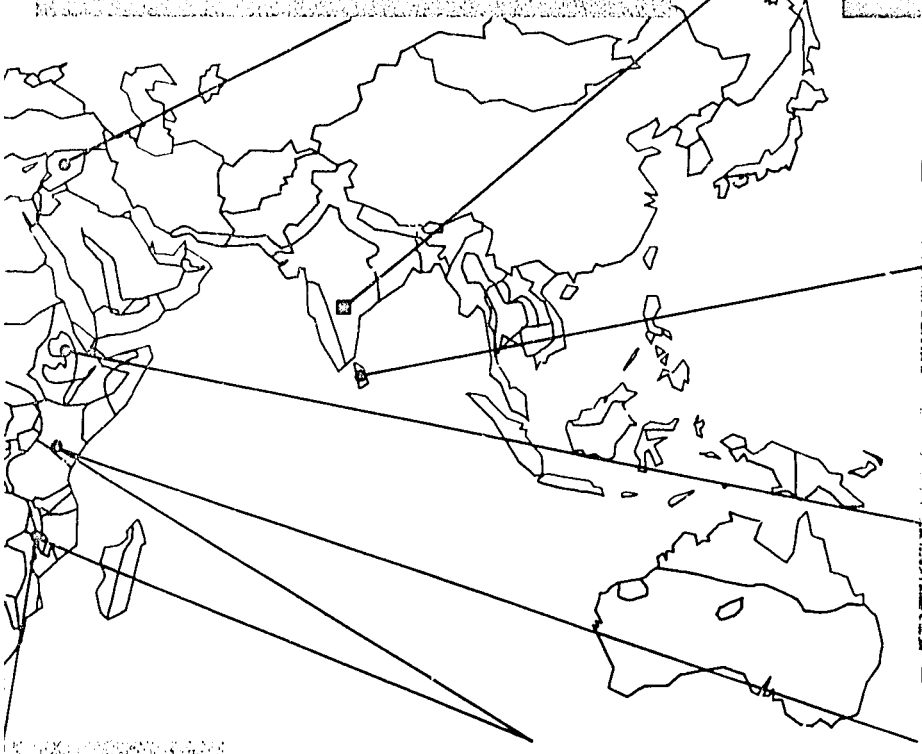
SADC/ICRISAT Groundnut Projec

ICRISAT's Locations

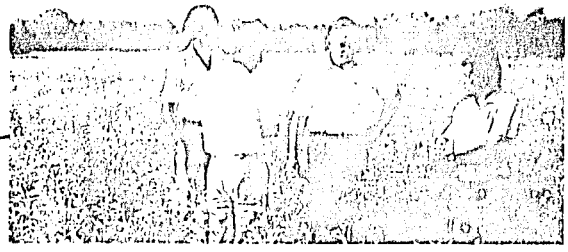
ICARDA/ICRISAT Chickpea Project — Syria

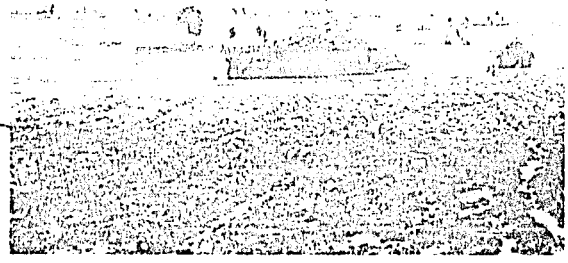


ICRISAT Center — India



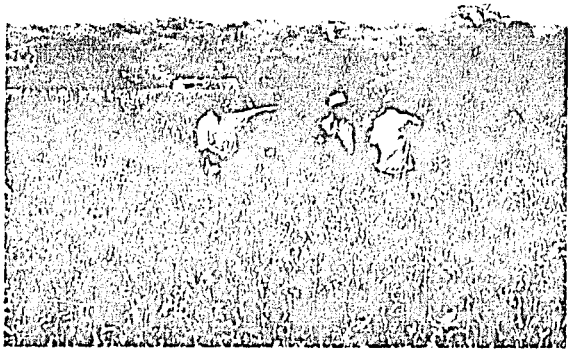
Department of Agriculture/ICRISAT Pigeonpea Production Project — Sri Lanka





ILCA/IAR/AUA/ICRISAT Joint Vertisol Project — Ethiopia

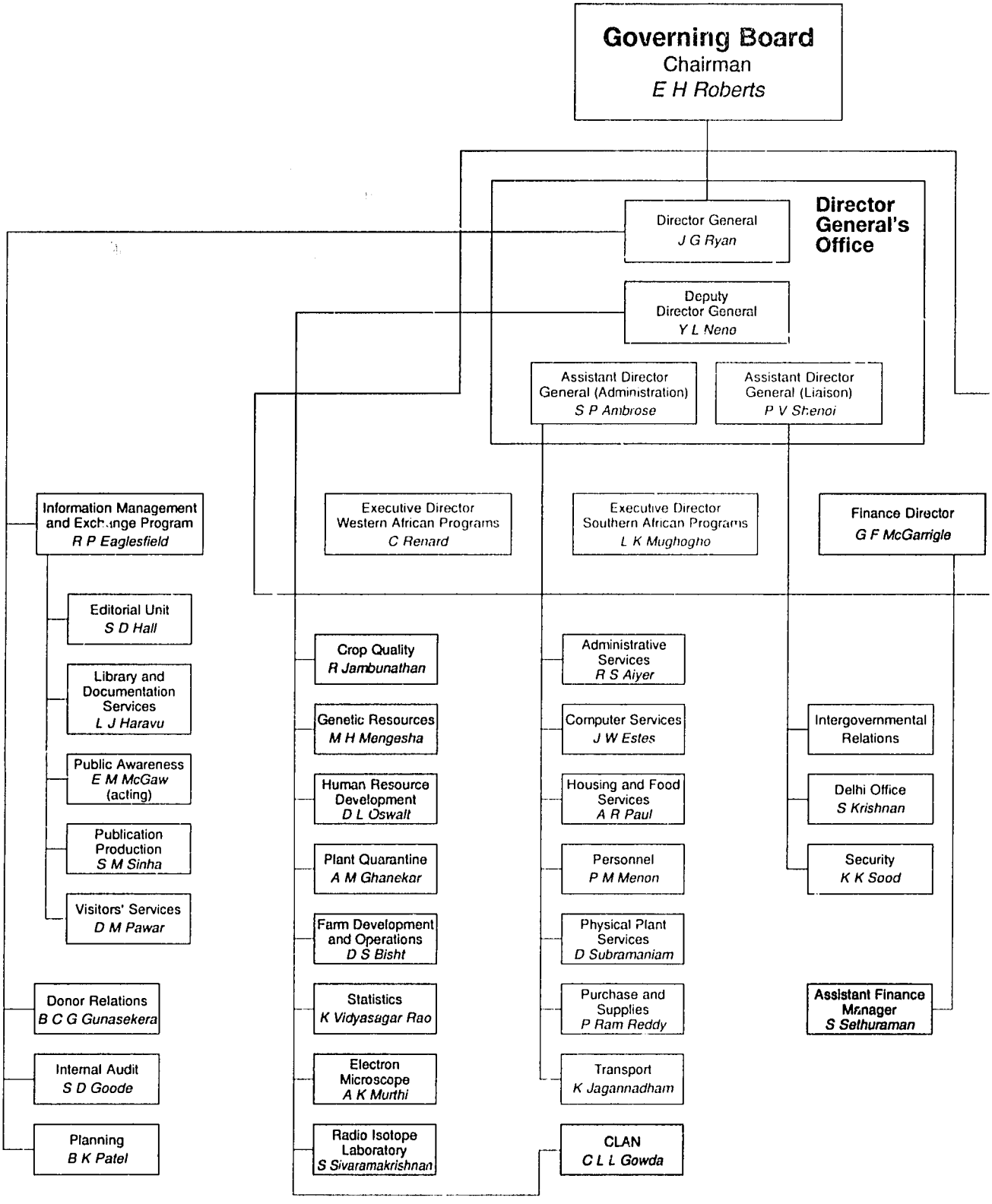
Malawi

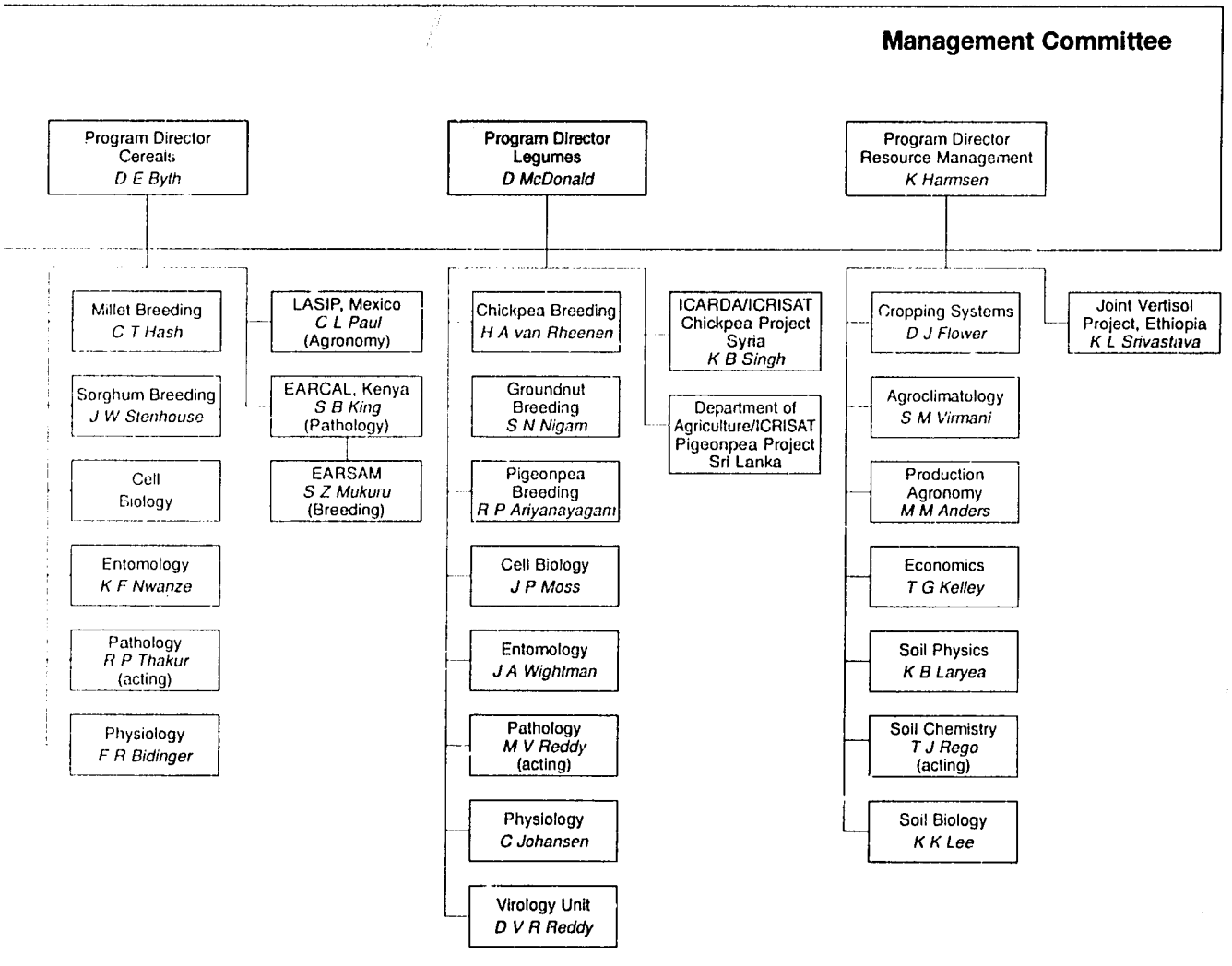


ICRISAT Pigeonpea Project — Malawi

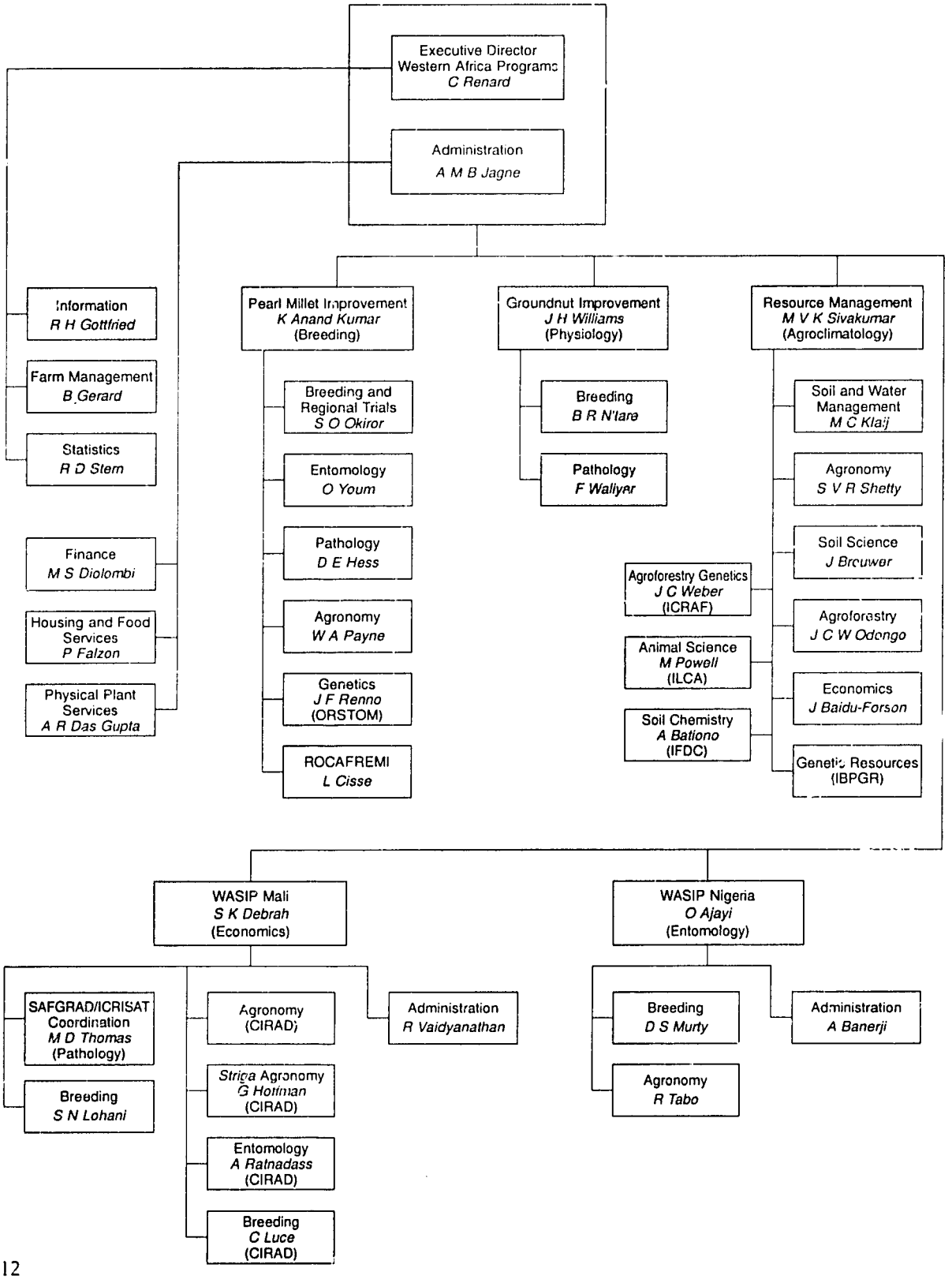
Eastern Africa Regional Cereals and Legumes Program (EARCAL) — Kenya

ICRISAT Center Organization

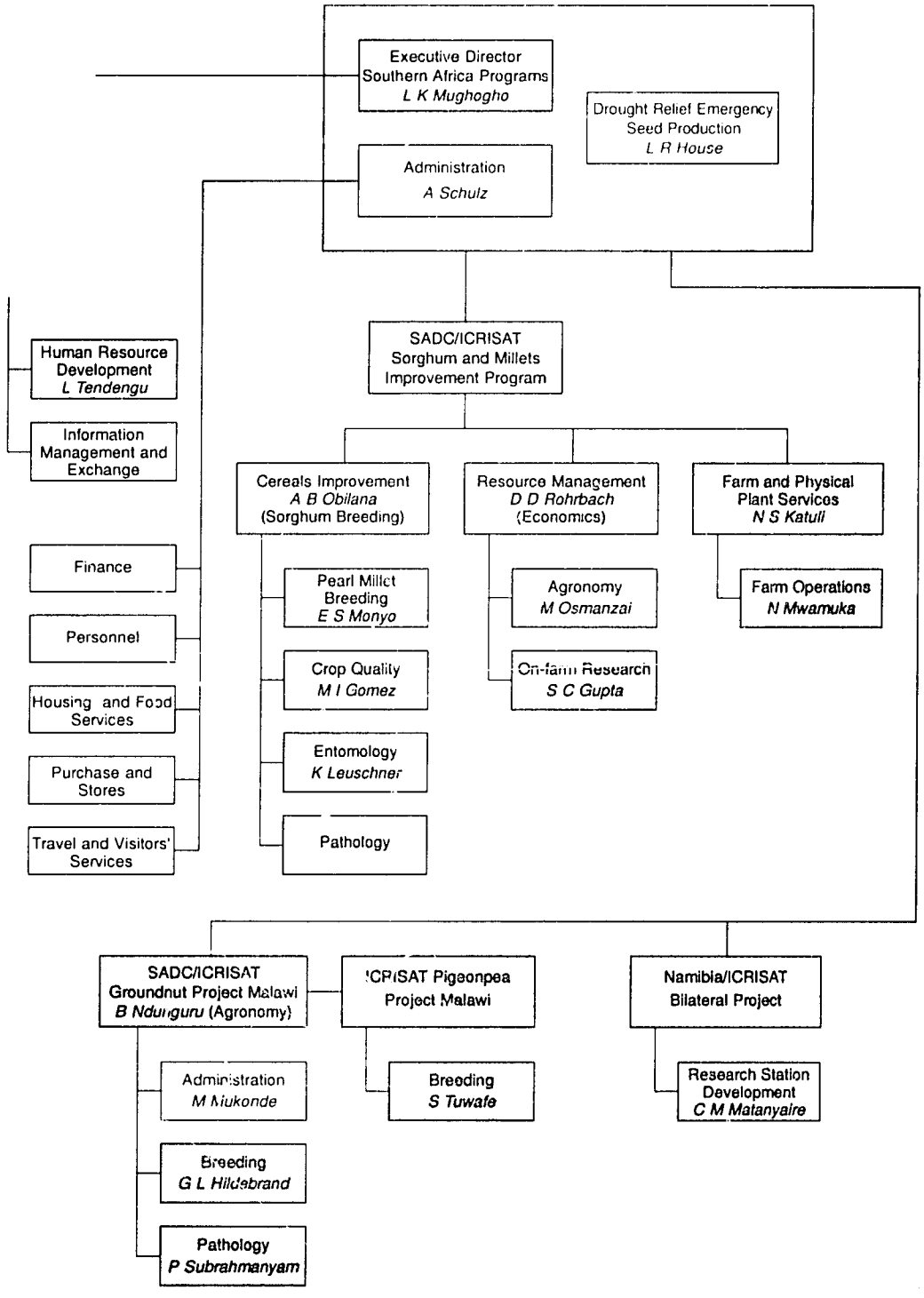



Management Committee
Program Director Cereals D E Byth
Program Director Legumes D McDonald
Program Director Resource Management K Harmsen
Millet Breeding C T Hash
Sorghum Breeding J W Stenhouse
Cell Biology
Entomology K F Nwanze
Pathology R P Thakur (acting)
Physiology F R Bidinger
LASIP, Mexico C L Paul (Agronomy)
EARCAL, Kenya S B King (Pathology)
EARSAM S Z Mukuru (Breeding)
Chickpea Breeding H A van Rheenen
Groundnut Breeding S N Nigam
Pigeonpea Breeding R P Ariyanayagam
Cell Biology J P Moss
Entomology J A Wightman
Pathology M V Reddy (acting)
Physiology C Johansen
Virology Unit D V R Reddy
ICARDA/ICRISAT Chickpea Project Syria K B Singh
Department of Agriculture/ICRISAT Pigeonpea Project Sri Lanka
Cropping Systems D J Flower
Agroclimatology S M Virmani
Production Agronomy M M Anders
Economics T G Kelley
Soil Physics K B Laryea
Soil Chemistry T J Rego (acting)
Soil Biology K K Lee
Joint Vertisol Project, Ethiopia K L Srivastava

Western Africa Programs Organization



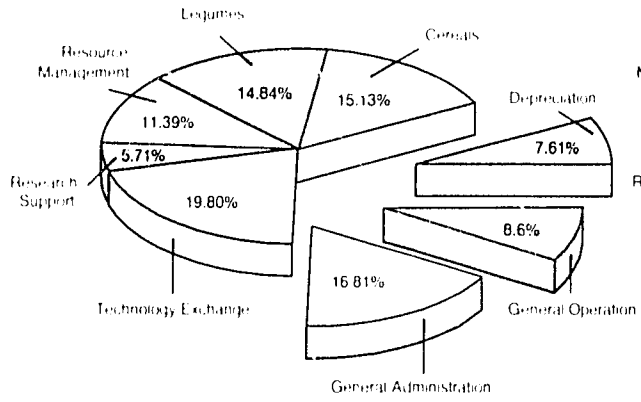
Southern Africa Programs Organization



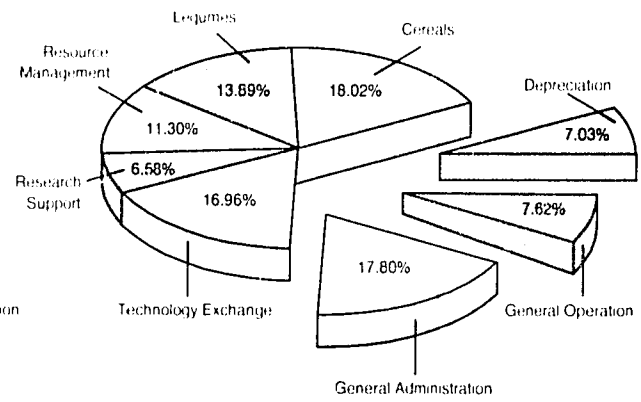
Financial Summary

Donor Contributions (Core and Complementary)		
	(US $ millions)	
	1992	1991
African Development Bank (AfDB)	0.6	0.2
Asian Development Bank (ADB)	0.4	0.6
Australia	0.7	0.6
Belgium	0.2	0.2
Bundesminister für Wirtschaftliche Zusammenarbeit/ Deutsche Gesellschaft für Technische Zusammenarbeit (BMZ/GTZ) Germany	3.0	2.5
Canada/Canadian International Development Agency (CIDA)/International Development Research Centre (IDRC)	3.2	2.7
European Economic Community (EEC)	2.3	3.2
Finland	0.2	1.1
France	0.4	0.5
India	0.1	0.1
International Fund for Agricultural Development (IFAD)	–	0.4
Italy	0.4	0.4
Japan	3.4	3.4
Netherlands	0.5	1.1
Norway	0.8	0.7
Sweden	0.9	0.8
Switzerland	1.9	1.5
United Kingdom/Overseas Development Administration (ODA)	1.6	1.7
United Nations Development Programme (UNDP)	1.7	1.7
United States Agency for International Development (USAID)	8.1	8.8
University of Hohenheim, Germany	0.2	–
World Bank	3.9	2.8
Other	0.1	0.3
Total	**34.6**	**35.3**

Resource Allocations (Core and Complementary)

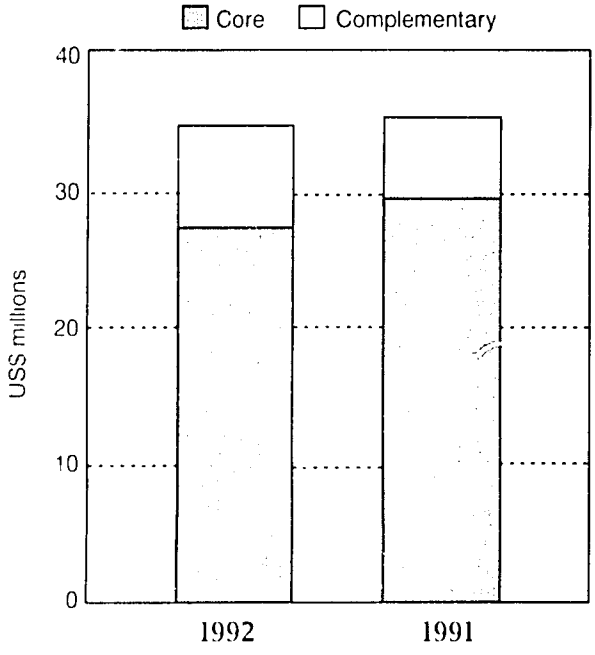


1992



1991

Funding



The decline in core funding from US$ 29.4 million to US$ 27.3 million and in total funding from US$ 35.3 million to US$ 34.6 million is compounded by the effects of inflation.

Balance Sheet

	(US $ '000)	
	1992	1991
Assets		
Cash and short-term deposits	14 438	7 584
Accounts receivable	7 204	12 394
Inventories	761	526
Prepaid expenses	354	327
Fixed assets - net	50 726	52 419
Total Assets	73 483	73 250
Liabilities		
Accounts payable and other	1 420	9 199
Accrued salaries and benefits	3 836	3 508
Payments in advance from Donors	6 054	2 475
In-trust funds	169	82
Capital		
Undesignated	56 152	54 735
Designated	5 852	3 251
Total Liabilities and Capital	73 483	73 250

Audited financial statements are available on request.

Highlights from ICRISAT 1992

This section provides highlights of the happenings and achievements of ICRISAT during 1992. It is not intended to provide a full historical coverage. Rather, this sample of events and accomplishments is selected to present an effective, and reasonably comprehensive, digest of ICRISAT's twentieth full year. In general, related topics follow each other as the selection of positive and worthwhile activities is covered, with no implication of relative importance conveyed by the sequence. Annual Reports that provide details of the Institute's scientific achievements are available from programs.

Developing the Medium Term Plan

A significant task for the year was the development of ICRISAT's Medium Term Plan (MTP) for 1994-98. This project was directed by a specially constituted MTP Task Force, but with the active involvement of all scientists across the Institute. It was determined that the Plan defining ICRISAT's agenda from 1994-98, should be the result of a decision-making process which:

- had clear criteria for establishing choices;
- was analytically rigorous, offering a consistent method for determining priorities;
- was based on empirical and intuitive judgements from a knowledge base within ICRISAT and the National Agricultural Research Systems; and
- was openly presented to and discussed among all the scientists.

A first step was to define and delineate domains throughout which the relevance of specific research themes is expected to be pervasive. For each domain, data were gathered on crop production, crop losses per constraint, and potential yield and economic recovery through research. Data on poverty and illiteracy were gathered for each domain.

From the many constraints identified, scientists selected 142 researchable topics, or research themes. For each research theme—generally encompassing several research domains—estimates were made of the economic value of successful research, taking into account potential yield gains, research and adoption lags, and anticipated ceiling levels of adoption of the resultant technology options. Computed net benefits took estimated probabilities of success into account, plus potential spillover of benefits from other regions and synergistic effects by simultaneous resolution of two or more constraints. Research costs were based on scientist staff requirements and other associated costs. In turn, this led to a projected net benefit-cost ratio for each of the 142 potential research themes. Intermediate research products (e.g., screening techniques, research methodologies, information) and milestones were also described—but not similarly valued.

Left: *A farmer harvesting her pearl millet crop in Niger.*

Computed net benefit-cost ratios are necessarily based on data resulting from scientists' judgements. To ensure that the most realistic judgements prevailed, data for each theme was presented and debated in open session involving scientists across the Institute. Scientists from national systems also contributed to this data-refining process.

From a number of possible quantitative/qualitative measures against which achievement of goals could be assessed, four criteria were selected as a basis for determining the relative importance of each theme. The chosen criteria were efficiency, equity, internationality, and sustainability. Measures for these indices were, respectively; net benefit-cost ratio, numbers of poor, and numbers of female illiterates (to measure the impact on specific targeted groups), the Simpson Index of Diversity (as a measure of the degree of internationality), and a subjective 1 to 5 scale of sustainability (to measure impact on the natural resource base). Values were agreed upon (through more iterative debate) for each of these measures for each theme.

A composite index was then computed incorporating all four criteria, with equal weights given to each. Themes were then ranked according to this composite index to generate a single list of prioritized research themes for the Institute. Scrutiny by management, consolidation of related themes across locations, identification of themes for complementary funding, and deletion of themes regarded as outside ICRISAT's domain, resulted in a portfolio of 92 ranked research themes for core funding. Subsequent sensitivity analyses have confirmed the robustness of the prioritizing technique used.

ICRISAT's draft MTP incorporates these 92 research themes, and identifies the funding level required for this research over the 1994-98 period. Should funding only be made available at a lower level, then the methodology provides valuable guidance regarding themes which would have to be dropped. Further, in a clear fashion, it identifies and quantifies the benefit streams which would have to be foregone and the milestones by which progress can be monitored and established.

A Decision Support System for Research Evaluation and Impact Assessment

1992 saw the establishment of a structured decision support system for research evaluation and impact assessment. It involves systematic development of information generation procedures that will provide a quantitative assessment of research priorities and research impact. This will only be achieved through extensive collaboration with scientists working in national programs throughout the SAT.

We look forward to being able to present more fully substantiated accounts of the impact of ICRISAT research in future ICRISAT Reports. Further, we anticipate having a more authoritative basis for decision making on future research themes.

The Gender Program at ICRISAT

ICRISAT's gender program was initiated in late 1991 when an economist was given the task of incorporating gender analysis into ICRISAT's research. This program embraces an important goal of the CGIAR system, promoting efficiency and gender equity to effect progress in agricultural development.

A late-1991 working group concluded that ICRISAT's gender program should focus on impact of new agricultural technology on both men and women, and on their differing roles in the practical implementation of these technologies.

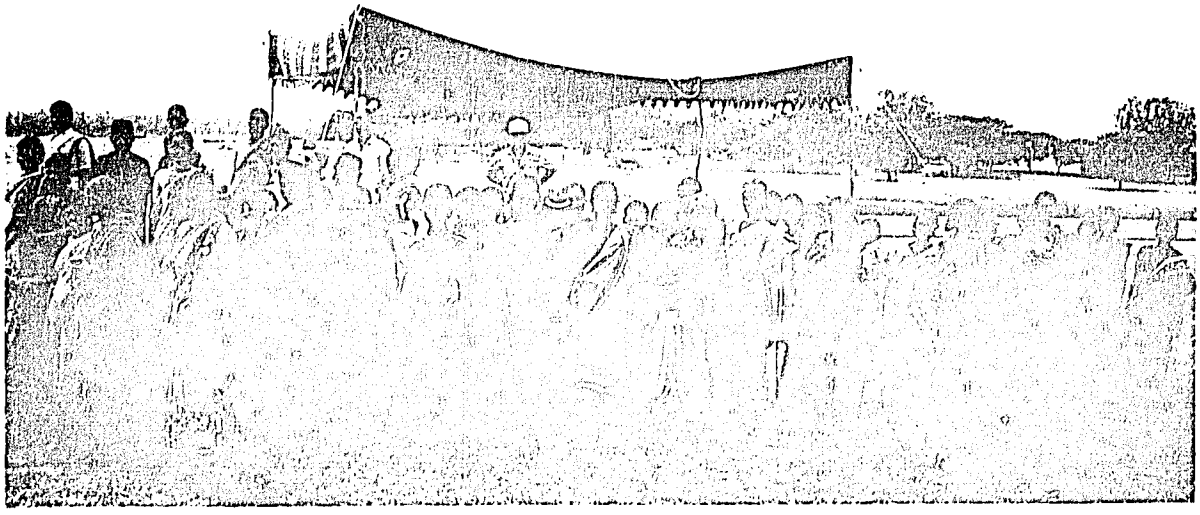
Responsibilities for some farming-household tasks are gender-specific.

Collaborative research between ICRISAT and the Central Research Institute for Dryland Agriculture aims to analyze the effects of SAT technologies on the roles and responsibilities of women and men members of varying groups of farm households in India. The information to be gathered will be used to quantify the significance of gender as a socio-economic variable in ICRISAT's research in India.

First Women Farmers Day at ICRISAT Center

Over the years, ICRISAT has organized many Farmers Days, but in September 1992, for the first time, a Farmers Day especially for women farmers was held at ICRISAT Center. The arrangements allowed participaints to directly observe a range of available technologies, and gave ICRISAT researchers an opportunity to get to know women farmers' preferences, problems, and opportunities through discussion groups.

The 800 women farmers who participated were delighted to have the opportunity to see the extent to which yields can be enhanced through the use of improved cultivars and better management. The farmers showed particular interest in farm machinery and equipment on display, and in technologies that reduce drudgery in the fields. They were keen to understand and acquire the designs of low-cost equipment for



Women farmers from Andhra Pradesh visiting demonstration plots of new groundnut varieties at ICRISAT Center.

weeding, threshing, and processing pigeonpea. Interest was shown in groundnut/sunflower and cotton-based intercrops. Several new cultivars in demonstration plots attracted considerable attention, both in the field, and during a taste-panel evaluation of foods made from improved varieties.

Many of the farmers' questions were related to various abiotic and biotic constraints and their alleviation. ICRISAT scientists suggested possible remedial measures including the use of resistant cultivars, and crop management and plant protection measures. The farmers said they would like to participate in a short training course in pest and disease management.

Several follow-up actions are planned. These include an evaluation of the performance of seeds that were distributed to the participants together with leaflets (in the relevant local languages) that explain how better to grow these seeds.

The day was a memorable one for ICRISAT staff who participated, and for the visitors who paid such close attention to everything that was said and shown to them. Their comments and requests will help ensure the relevance of future research.

Developing Alternative Indicators of Food and Nutrition Security in the Indian SAT

Food security (defined as access to sufficient food for all people to ensure a healthy and productive life) is often taken as a measure of rural welfare. However, determining an actual value for 'food security' through field research is an expensive and time-consuming process. The determination of such 'traditional' indicators of food security

as household income or individual dietary intakes, involves considerable resources and efforts in collecting data from detailed household surveys and analyzing these data. There is a need to find alternative and accurate indicators that are quick, inexpensive, and relatively simple to analyze.

The search is on in a collaborative project, now in its second year, that involves ICRISAT, the Rockefeller Foundation, the International Food Policy Research Institute (IFPRI), Andhra Pradesh Agricultural University, the National Institute of Nutrition, Hyderabad, individual scientists from Johns Hopkins University, and the National Institute for Mental Health and Neuroscience, Bangalore. Their work involves field testing and documenting the validity and reliability of alternative indicators of food and nutrition security in the Indian SAT.

Economic, nutritional, and biochemical data are currently being collected in four villages. Quantitative and qualitative results should be available by early 1994. Companion studies by IFPRI are in progress in Malawi, Kenya, and Mali. The end results of all these studies will be synthesized and compared. This synthesis of information will eventually provide an understanding of the general applicability, and hence global usefulness, of the proposed indicators.

As an adjunct to this work the health and nutritional status of such vulnerable groups as women and pre-school children in villages where ICRISAT has conducted studies for many years is being re-evaluated, to provide a 'benchmark' statement on the nutritional status of such groups. This benchmark can be compared with internationally recognized earlier studies, and will allow ICRISAT to understand how rural welfare has changed over the years.

Collecting data from the villagers in Kandi, Andhra Pradesh, India.

Economics of Soil and Water Conservation

Soil and water conservation (SWC) is an important component of improved dryland agricultural practices in the SAT. Appropriate conservation measures help to retain moisture and nutrients needed for plant growth. They promote sustainability by reducing the land degradation resulting from soil erosion. Over 10 billion rupees (approx. US$ 1 billion) has been spent in India in the development of SWC practices, but, in general, they have not been adopted by farmers.

In collaboration with Winrock International and the Indian national program, a project is attempting to discover why farmers reject recommended practices, and why some farmers adopt indigenous measures independently of special SWC programs in the

Constructing stone contour bunds to retain valuable surface soil and conserve moisture in Karnataka, India.

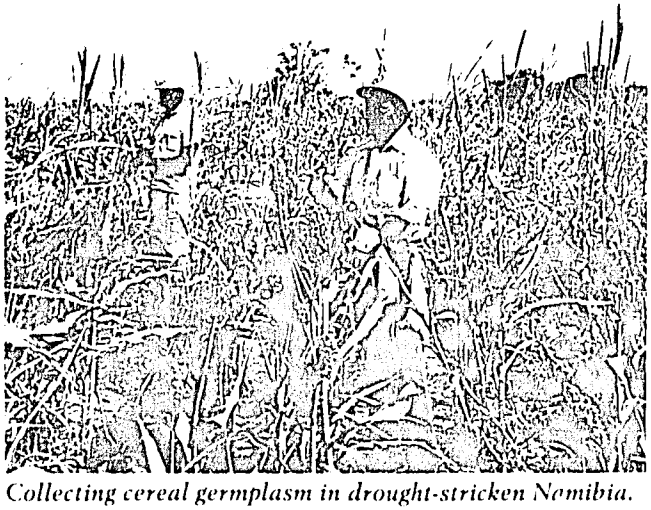
Indian SAT. The hypothesis to be tested in the study is that farmers are aware of erosion, but that recommended practices do not suit their needs.

The primary clients of this study are researchers who can design more suitable technologies given information on the rationale by which farmers accept some practices but reject others, and development program administrators who can design more cost-effective extension approaches if they understand the circumstances under which different types of farmers invest in SWC.

Saving the Genes

During the 1991/92 growing season, southern Africa was gripped by the worst drought of the century. Whilst the people were reeling under the drought, there was also a risk of massive loss of biodiversity in the region. If timely steps were not taken, traditional landrace varieties of crop plants could be lost.

A germplasm collection mission, sponsored by the Asian Development Bank and ICRISAT, covering Namibia, Zambia, and Zimbabwe was launched jointly by ICRISAT Center, the Southern Africa Development Community (SADC)/ICRISAT Sorghum and Millets Improvement Program(SMIP) based at Matopos, Zimbabwe, the SADC Regional Gene Bank (SRGB), in Zambia, and the national programs of the three countries The collection team worked for 6 weeks starting in early April, covering areas not previously explored, and salvaged germplasm from drought-affected areas for conservation and future use.



Collecting cereal germplasm in drought-stricken Namibia.

The rescue mission was successful. A total of 128 cultivated and 17 wild and intermediate pearl millets, 67 cultivated sorghums, 7 wild and intermediate sorghums, and

17 cultivated and 1 wild finger millets were collected. Sixty-nine samples of cultivated groundnuts were also collected. Sets of the collected seed samples were provided to the national programs in all three countries, to SADC/ICRISAT Sorghum and Millets Improvement Program (SMIP), and to the SRGB.

At ICRISAT Center the collected germplasm is being evaluated for a range of characters including drought tolerance, disease resistance, yield, and seed quality. All the collected material is being conserved in ICRISAT gene bank, and is available for research and as an insurance against any future loss of material in the SADC region.

Turning Disaster into Opportunity

In February 1992, because of the severe drought it was clear that southern Africa faced a disaster situation. Food would have to be imported and, equally important, the availability of seed for sowing after the drought was going to be a serious problem.

Scientists of SADC/ICRISAT SMIP realized the seriousness of this problem and conceived an innovative project which combined the tactical production and distribution of seed to farmers with the strategic opportunity to achieve broad adoption of improved cultivars in the region.

An arrangement was made with the farmer-owned Zimbabwe Seed Co-operative to produce sufficient seed of PMV 2, Zimbabwe's recently released pearl miliet variety that was developed in collaboration with SMIP, to sow over 25% of the pearl millet hectarage in that country.

The United States Agency for International Development (USAID), principal donor for the project, asked SMIP to determine the seed requirements of other southern African countries. Malawi, Namibia, and Zambia asked for seed and ultimately, six varieties were selected; three pearl millets and three sorghums.

The Gwembi Valley Development Company of Zambia agreed to lease nearly 1000 hectares with irrigation support on the shore of Lake Kariba. Another 200 hectares in Malawi's Shire Valley were made available by the Malawi Department of Agricultural Research, but due to low water levels in the valley's rivers and streams, only 30% of the Shire Valley area could be sown, and for want of water, yields were so low that only 11 tons of seed were produced there.

USAID provided funding in Malawi, Namibia, and Zimbabwe. The Government of Zambia, with USAID assistance, supported the project in Zambia. The Canadian International Development Agency provided operational costs for all four countries.

Digging a channel from Lake Kariba to make water available for vital seed production in Zambia.

Despite the prolonged drought, over 930 tons of seed (743 tons of sorghum, 178 tons of millet) were produced from the Gwembi Valley site. The seed was processed and distributed to farmers in the three countries. As a result farmers in drought-afflicted areas should be able to harvest over 150 000 hectares of improved sorghum and pearl millet at the end of the 1992/93 season.

The drought has passed, the rains have come. The new season promises to be a bountiful one. Thousands of farmers in the region have been provided with an opportunity for a fresh start. Increasing the availability of basic food in places where food security is at risk is a fundamental challenge for international development agencies. This story is a splendid example of positive response to a crisis situation through practical collaboration between national programs, donor agencies, private industry, and SADC/ICRISAT SMIP.

SADC Sorghum Hybrids Do Well in the Drought

Over the past few years the comparative advantage of sorghum hybrids over open-pollinated varieties has been monitored by SADC/ICRISAT SMIP scientists. In 1991/92 they compared the agronomic performance of 28 sorghum genotypes: 5 local varieties, 11 improved varieties, and 12 hybrids from the national sorghum breeding

programs in Botswana, Zambia, and Zimbabwe. The materials were grown under two soil-moisture regimes.

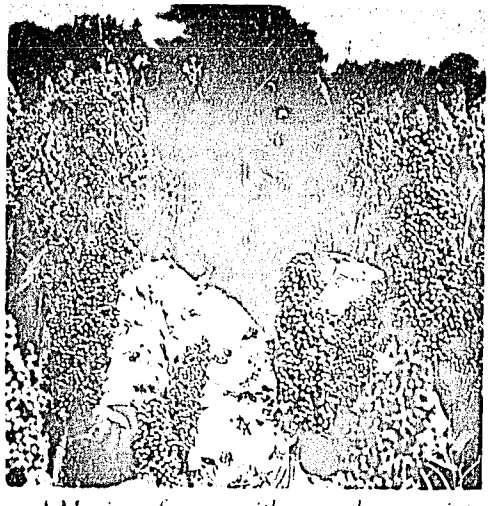
During a season that was seriously affected by the drought that hit southern Africa, the superiority of sorghum hybrids over the open-pollinated varieties was confirmed. The 12 sorghum hybrids produced 21% more grain yield than the 11 improved varieties when irrigated, and 36% more grain yield when rainfed. The hybrids had a photosynthetic rate 22% higher when irrigated, and when rainfed their rate was 8% higher than that of the open-pollinated varieties.

A farmer in Zimbabwe in her sorghum crop that produced well despite the drought.

Mexican Farmers Score with Sorghum

Two years ago ICRISAT's Latin American Sorghum Improvement Program (LASIP) entered into an agreement with the Farmer Credit Section of the Bank of Mexico to support a collaborative project to develop new cultivars for use by farmers in the south central state of Morelos. At the time of the project's inception, the 35 000 hectares of cultivated sorghum in Morelos consisted entirely of imported hybrids, but both the seeds and the chemicals required to grow them were too expensive for the average farmer.

Phase I of the project consisted of testing new crosses of sorghum in farmers' fields without using irrigation or expensive chemicals. This work resulted in the selection of four ICRISAT-bred varieties, which the farmers named Mapaztlán, Morelos, Xalostoc, and Zapata. In large on-farm tests under similar conditions, they proved superior in adaptation to tropical conditions and higher-yielding than the imported hybrids.



A Mexican farmer with a sorghum variety that outyielded imported hybrids.

During Phase II in 1992 farmers sowed the four varieties on 400 ha of nonirrigated farmland. This time

they produced twice the yield of the imported hybrids. Xalostoc, for example, yielded well over 9 t/ha compared to the 3.5 t yielded by the hybrid. Significantly, the ICRISAT varieties were free from leaf diseases while the hybrids were heavily infested.

The Bank of Mexico has approved funding for Phase III in 1993, when the seed will be multiplied to enable farmers to sow 1800 hectares during the summer crop cycle. Caudillo del Sur, the farmer group that has now taken over the project from the LASIP scientists, has fully accepted the new varieties.

Quality Counts

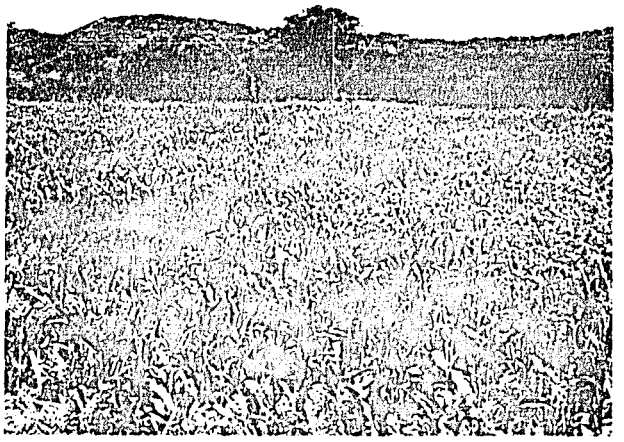
Many factors influence adoption of new varieties by farmers, and they vary considerably in different environments. Two important factors are post-harvest characteristics and consumer preference.

Villagers in Mali waiting to evaluate the food qualities of introduced sorghum varieties.

In collaboration with food technology scientists from Mali's Institut d'économie rurale, members of ICRISAT's West African Sorghum Improvement Program (WASIP) recently conducted tests involving a number of farmers in three Malian villages. The evaluation compared the dehulling, milling, and food qualities of four WASIP-introduced sorghum varieties with those of a local cultivar. Two of the introduced varieties that were bred by ICRISAT were found to combine acceptable processing and food qualities. These two varieties will be further screened by WASIP to increase their chances of being more widely adopted in western Africa.

In southern Africa, an evaluation was made of the grain quality of 82 cultivars of advanced, pre-released, and released sorghums, tested in two seasons (1989/90 and 1990/91) and in nine SADC countries. Twelve physical parameters were used to characterize grain quality. Using a matrix of these quality parameters it was possible to make selections for such specific end uses as milling or brewing.

The evaluation data show that white and red-grained sorghums have superior milling properties to brown-grained sorghums, which have significantly lower kernel weights, softer endosperm, lower grain density, higher water absorption, and darker flour. Brown-grained sorghums, however, are more suitable for malting and/or brewing than white-grained varieties.



Screening sorghum hybrids at Matopos, Zimbabwe.

Screening 120 improved sorghum hybrids developed by SMIP, and the Zambian and Zimbabwean national programs, revealed a wide range of genetic variability in malting quality. The tests confirmed that colored-grained types were superior to those with white grains, while differences between brown- and red-grained types were not significant.

Good News in the Fight Against Grain Molds

Preharvest weathering damage in sorghum can result in substantial losses due to grain mold caused by a number of fungi. Grain mold resistance is available in colored-grained sorghums, but, until recently, there has been limited success in identifying resistance in white-grained sorghums.

ICRISAT scientists have developed a new two-stage screening technique that involves a rapid, inexpensive laboratory screening, followed by a field evaluation. Laboratory screening involves inoculating seeds with the spores of three grain mold fungi, transferring inoculated seeds to pre-sterilized humidity chambers, and incubating them for 5-6 days. At ICRISAT Center when 66 photoperiod-sensitive, white-grained sorghum accessions from 7 countries were tested, 14 lines showed moderate to high degrees of grain mold resistance to three major grain mold pathogens. Seedlings of the 14 resistant genotypes were transplanted into pots, and induced to flower 21 days

Guinea sorghums contain valuable sources of genes for resistance to grain molds.

White-grained sorghums are more affected by grain mold than colored-grained sorghums.

later by manipulating the amount of daylight they received. When the panicles emerged, the pots were moved to the grain mold nursery in the field where high humidity was maintained using overhead sprinklers. The panicles were then inoculated with a mixture of spores of the three grain mold fungi. Fifty-five days after inoculation, four entries had not developed grain mold, and a further six were only moderately infected. This test showed that photoperiod-sensitive sorghums of the white-grained guinea type include sources of genes for resistance to grain molds. Using this technique, other accessions in the ICRISAT gene bank can be rapidly tested. Identification and characterization of sources of resistance will provide the basis for breeding programs to introduce much-needed resistance into white-grained sorghum genotypes that have other desirable attributes.

Increasing Adoption of Improved Sorghum Genotypes

Adoption of improved sorghum hybrids and varieties in parts of the Indian SAT is often limited. There are many possible reasons for this. Some production-linked factors include a preference by farmers for a different grain/fodder ratio; improved performance may require a package of improved variety and management inputs; hybrid seed is expensive and may not be available; and improved genotypes may be more susceptible to pest and disease attack under farmers' conditions. Effective design of crop improvement research requires an improved understanding of the factors influencing adoption by farmers.

ICRISAT scientists are working together with the Indo-Swiss Livestock Project, a bilateral project with the Andhra Pradesh State Livestock Programme funded by the Swiss Government, in a rainy-season sorghum-growing area of Andhra Pradesh, India. The Project aims to determine sorghum farmers' preferences, the links between sorghum and livestock production, and to quantify sorghum management practices and identify production constraints.

A group of farmers who farm in reasonably close proximity were each given one sorghum genotype to sow and manage in the same way they manage their traditional

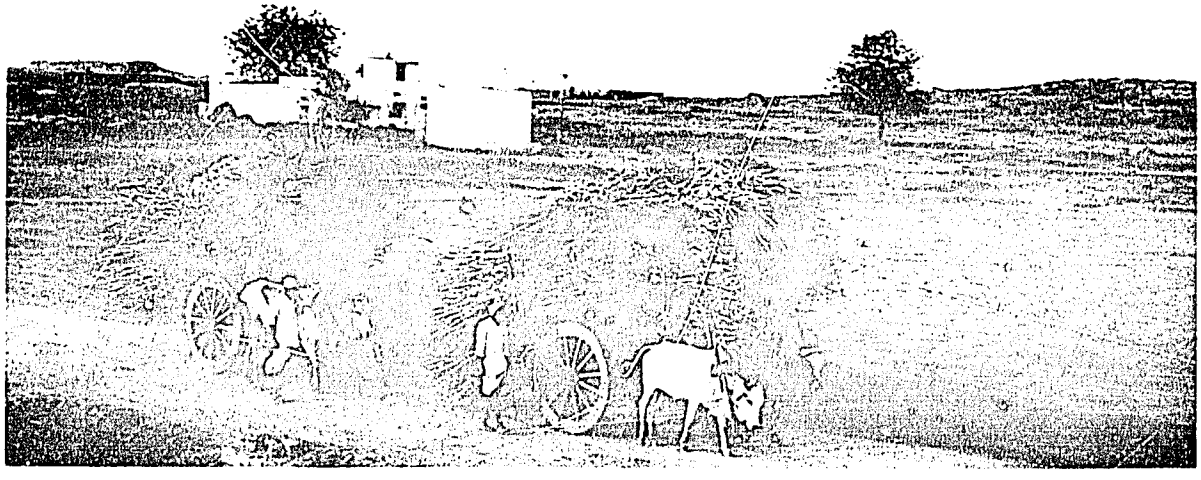
genotypes. Farmers were interviewed before they received the seed and each project field was monitored fortnightly during the growing season. At the end of each season the qualities of the grain and fodder produced by the hybrids or improved varieties grown by the farmers were evaluated and compared to local cultivar production.

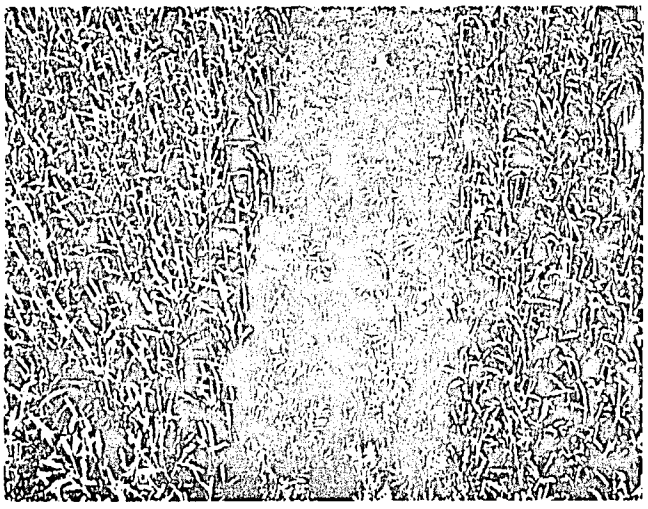
An ICRISAT-bred sorghum variety growing in a traditional mixed cropping system.

Two seasons of on-farm trials are now complete, and nine sorghums have been evaluated. Two ICRISAT-bred varieties have been selected by farmers as being preferable to their traditional sorghums; a multi-purpose grain type, which produces good fodder in marginal environments and has strong resistance to sorghum midge, and a grain type. In selecting these two varieties farmers explained that, although they prefer sorghum to rice straw for fodder, since adequate quantities of rice straw are available in the area, there is no strong demand for sorghum straw. The farmers preferred multi-purpose sorghums and in all cases the improved genotype selected by farmers outperformed the traditional genotype regardless of management level. All the farmers rejected hybrid seed as being expensive and hard to acquire.

Seed of the selected sorghums will be distributed by the Indo-Swiss Project in large enough quantities in the study area to further assess the chances of adoption and impact. The on-farm trials will be extended to a postrainy-season sorghum-growing area and an additional rainy-season area in 1993. Giving the farmers what they have chosen themselves has a good chance of effectively increasing their productivity.

Sorghum fodder on its way to market in Andhra Pradesh, India.





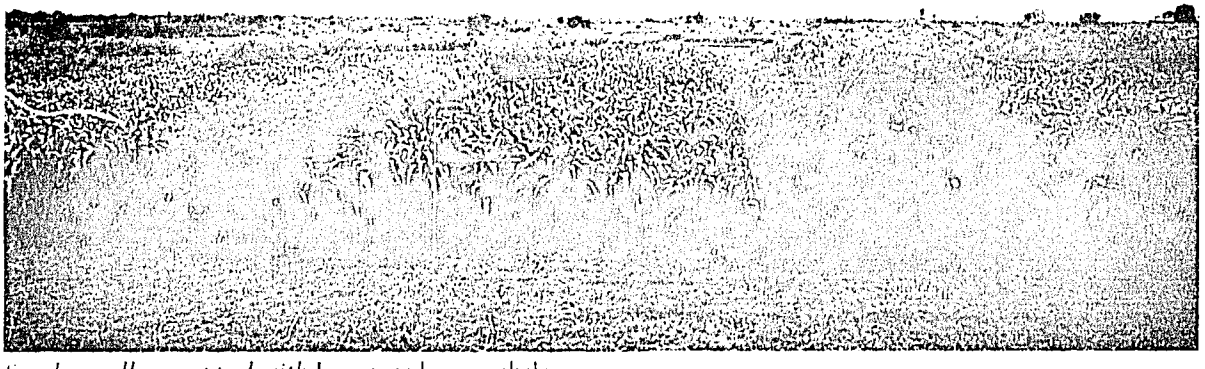
Pearl millet alley-cropped with Leucaena leucocephala.

Fodder Production and Agroforestry

Animal husbandry is an important practice in the drylands of the SAT, with success dependant on the regular availability of browsing materials. However, the quantity and nutritional value of browse available to livestock are subject to unpredictable seasonal fluctuations. In addition, many woody species and annual/perennial grasses are unproductive throughout the long dry season, so green fodder is scarce for 7-9 months of every year.

A major constraint to the adoption of agroforestry systems in the SAT has been the competition between trees and annual crops for available resources. Two ways of managing interactions between trees and annual crops in agroforestry systems have been researched at ICRISAT Center. The first strategy showed that alley cropping pearl millet with *Leucaena leucocephala* was more productive and gave a better economic return than either pearl millet or *Leucaena* grown alone.

In situations where subsistence farmers must grow food crops, an agroforestry system will only be acceptable if annual crop yields are not reduced by the perennial species. In conventional alley cropping systems, perennials often have a competitive advantage. The second research project at ICRISAT Center assessed a different management strategy which shifts the advantage to the annual crop. Under this stragegy in a *Leucaena*–sorghum alley cropping system the *Leucaena* was cut to ground level



Sorghum alley-cropped with Leucaena leucocephala.

just before the sorghum was sown. This alley-cropped sorghum then performed similarly to a sole crop of sorghum. The new system has the added advantage of flexibility. A farmer may decide not to cut the *Leucaena* at the time the sorghum is harvested because the sorghum straw provides sufficient fodder at this time. However, the *Leucaena* still has the potential to provide two fodder harvests before the next rainy season.

Improving the Role of Livestock in Millet-based Cropping Systems in the Sahel

In a major shift in semi-arid western African farming systems, livestock are increasingly seen as a tactical investment opportunity, and as a means of stabilizing food availability in marginal years for crop production. The application of animal manure sustains yields in many cultivated areas, while crop residues, weeds, and browsing provide feed for livestock during the 6–8 month dry season. However, the depletion of vegetative cover through grazing and/or harvesting crop residues to feed livestock leaves the soil bare and susceptible to wind erosion. Transfer of nutrients from rangeland in order to support crop production can impact on the longer-term viability of the integrated system.

Overgrazing by livestock renders Sahelian soils susceptible to wind erosion.

Preliminary results of a 1991/92 survey by International Livestock Centre for Africa (ILCA) staff based at the ICRISAT Sahelian Center in three villages in southwest Niger indicate that farmers prefer goats, and are not necessarily interested in accumulating livestock as a store of wealth. Producers are making long-term efforts to develop and improve their livestock as part of mixed farming systems.

In an ILCA/ICRISAT on-station collaborative project, scientists found that, because it is high in fiber and low in protein, millet straw is difficult to digest, but its feeding value could be improved. Millet leaves from plants with the genetically controlled brown-midrib trait had 42% less lignin, and were 5% more digestible than normal leaves.

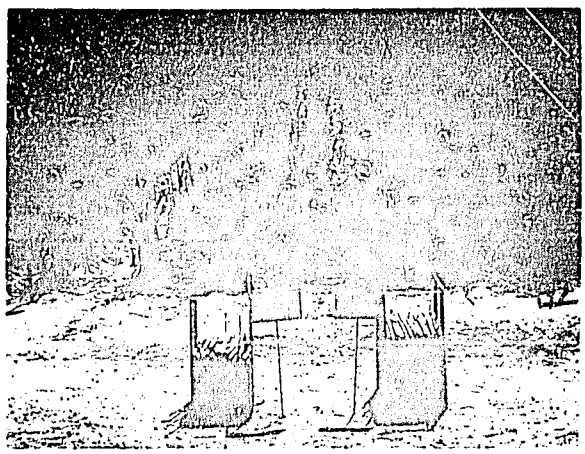
Millet leaves with brown midribs make good fodder.

ILCA researchers found that when animals are corralled, even for a single night, their urine and faeces are more beneficial to the soil than hand-spread manure alone. Corralling livestock on cropland has a long-lasting effect on millet yield.

Livestock can play a positive role in sustaining millet production in mixed farming systems in the Sahel. The long-term trials now in progress at the ICRISAT Sahelian Center will provide information on how management can be improved to minimize nutrient losses and contribute to sustainable agricultural production in this region.

New Hybrids Offer Fresh Hope

In the next 20 years, as populations grow, the demand for cereals will nearly double in western Africa. In India, the development and production of single-cross pearl millet hybrids in the 1970s and 1980s led to spectacular yield increases. Unfortunately, the basic materials used are too early-maturing and too susceptible to downy mildew disease to be useful in western African breeding programs.



In rainy season 1992 trials at the ICRISAT Sahelian Center, the intervarietal hybrid on the right produced 38% more grain than the variety on the left.

At the ICRISAT Sahelian Center, breeders have now shown that if inbred lines derived from variety crosses are used as female parents, and improved varieties are used as male parents, the resultant hybrids (referred to as intervarietal hybrids or IVHs) have interesting characteristics—they are less uniform than single-cross hybrids; they have higher levels of downy mildew resistance; and since an improved variety is used as a male parent, adaptation problems are minimal. Further, the cost of developing male-sterile lines is avoided.

In a trial in 1989 IVHs flowered earlier, had less downy mildew, and yielded up to 80% more than the local cultivar. Following these encouraging results, a range of inbreds was used in combination with five improved varieties to generate 122 IVHs that were tested in five preliminary trials in 1990. The IVHs produced up to 175% more grain than their male parents. When retested in 1992, 28 selected IVHs produced 20-100% more than their male parents, and up to 50% more than the local cultivar. They were also less susceptible to downy mildew than the local cultivar.

Further work has begun to evaluate promising IVHs in collaboration with national programs in the Sahelian region. Procedures for seed multiplication are being developed, inbred plants that would adversely affect the yield of IVHs are being identified, and IVHs' response to improved management is being tested. It is hoped that in the near future IVHs will make a significant contribution to increased pearl millet productivity in the Sahelian region.

Finding the Best Millet for Rajasthan and Beyond

The area of pearl millet sown to three ICRISAT-derived cultivars in India is estimated at around 3.5 million hectares, or about one third of the total. These cultivars have resistance to downy mildew disease. Conservative estimates indicate that their use results in more than US$ 54 million worth of extra food each year.

However, these improved varieties of pearl millet do not thrive everywhere in the semi-arid tropics. For some areas they are too late-maturing, or too susceptible to heat at the seedling stage, or do not produce the type of fodder the farmers need. For example, the hot dry millet-growing areas of Rajasthan are similar to those found in large parts of the millet-growing areas of sub-Saharan Africa, where stress levels are high, yield levels are very low, and crop-livestock interactions are crucial to farming systems. In these situations, local millet landraces can out-yield released cultivars. ICRISAT breeders are developing varieties tailored to these stress conditions. Scientists at research stations in Rajasthan and neighboring areas have now joined ICRISAT in collaborative variety development projects, using crosses of local materials with improved breeding stocks of African origin. These efforts have had rapid success. Rajasthan authorities have released a variety and a hybrid, and others are well on their way to farmers' fields.

One of these studies is designed to improve breeders' understanding of the impact of the major constraints to production in the different agro-ecological zones of Rajasthan, and of farmers' preferences for varietal characteristics of pearl millet. Farmers have been encouraged to experiment with new varieties in their own fields, and their experiences and reactions are fed back into the breeding program.

Initial results indicate that low soil fertility is the most important overall constraint to production, and that poor farmers, especially women, have a strong preferences for early-maturing varieties. Having sufficient food to subsist is more important than providing livestock fodder. In western Rajasthan, where heat and drought are particularly severe, seedling establishment is more important than in less-extreme environments. Breeding materials identified in this study are being used to map the genes for heat

Women farmers in Rajasthan discussing the pearl millet samples they selected from collaborative breeding trials.

tolerance in collaborative research with the Institute of Grassland and Environmental Research, funded by the Overseas Development Administration, UK.

Farmers, and government and nongovernment organizations are active collaborators in the project and are directly involved in the formulation of new research priorities, and in the development and exchange of technology. In this way, impact is immediately identified and extended, and policy adjustments are possible.

This work is demonstrating that new varieties can be tailored to specific environmental niches and to farmer preferences in marginal areas. The innovative methodologies involved are likely to result in increased relevance and adaptability of research results in a wide range of agricultural practice.

Seedling Heat Tolerance in Pearl Millet

In the harsh environments of the Sahel and Rajasthan in India, the ability of seedlings to withstand high soil temperatures is an important factor in crop establishment. Field screening for seedling heat tolerance is possible, and is in progress at Fatehpur, Rajasthan; but it is expensive, and success is dependant on highly variable environmental conditions. If the reasons for heat tolerance were understood it should be possible to devise more efficient screening methods.

A 5-year collaborative study with the Institute of Grassland and Environmental Research (IGER), UK on comparative methods of selection for seedling thermo-

tolerance is now in progress, and is using data from earlier work in Rajasthan. The project is also evaluating the genetic variability for seedling heat tolerance in elite cultivars.

Initial results are very encouraging. A special population has been developed from a cross between a highly tolerant landrace from Rajasthan and a newly released ICRISAT pearl millet variety. Collaborative research has demonstrated that the variation seen under field conditions is heritable, but that selection based only on germination at high temperature is not effective.

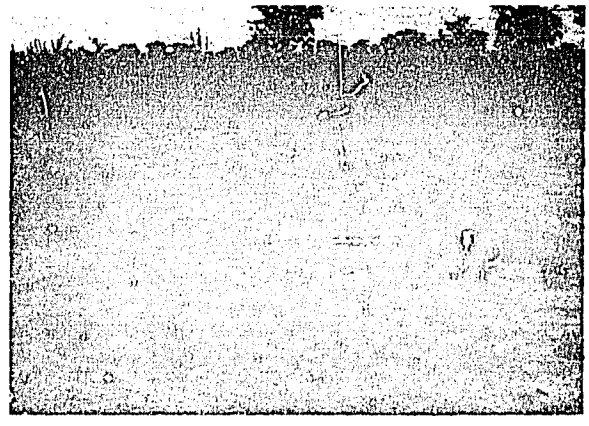
Pearl millet seedlings at the stage they are most vulnerable to heat stress.

The research is now moving further upstream in attempting to identify markers for genes contributing to the seedling heat tolerance of an elite inbred line from Haryana Agricultural University. The production of tissue samples and seed of the mapping populations are conducted at ICRISAT Center, while gene mapping and laboratory screening of the progenies is done at IGER. Following recombination of the selected progenies at ICRISAT Center, field testing of the recombined populations will be done at Fatehpur.

If successful, these combined research efforts will provide major breakthroughs in ICRISAT's ability to maintain and improve seedling heat tolerance in breeding materials intended for the most inhospitable parts of the SAT.

Small Variations May Help to Spread the Risk

Within the sandy soils of the Sahel there are wide variations in nutrient and water availability. As a result, yields over distances as short as a few meters can be very different. This has typically been seen as a problem to be eliminated through tillage or the application of fertilizers, crop residues, or manure. However, analysis of experimental results from the ICRISAT Sahelian Center, in co-operation with researchers from the Universities of Wageningen and Hohenheim, has led to a reinterpretation of the effects of soil and crop growth variability on farm productivity in the Sahel.



Uneven crop stand in a farmer's groundnut field near Gaya, Niger.

Millet plants growing under Faidherbia albida *trees can be affected by dry spells.*

Initial results from a long-term study at the ICRISAT Sahelian Center indicate a virtual reversal in the pattern of relatively good- and poor-yielding areas of pearl millet and cowpea between 1984 (a drought year) and 1985–88. It appears that slightly higher, drier, and more fertile areas produce relatively well during years of good rainfall, whereas slightly lower, wetter, and more leached areas are better during poor rainfall years.

In a collaborative experiment a less-fertile plot produced 0.63 t/ha in 1989 and 0.68 t/ha in 1990, while a more fertile plot produced 1.81 t/ha in 1989, but only 0.26 t/ha in 1990. Detailed analysis showed that in the more fertile plot, crop development was faster in both years. In August 1990, millet in the more fertile plot was beginning to flower when a 3-week drought resulted in aborted florets and subsequent yield loss. In the less-fertile plot, where crop development was slower, the plants withstood the dry spell at a less sensitive development stage, flowered, and filled grain as in the previous year. Had the whole experimental field been as uniformly fertile as the first plot, grain yield would have been uniformly low.

Further observations were made in farmers' fields around the ICRISAT Sahelian Center in 1991. Under the leafless *Faidherbia albida* trees in May, millet plants grew quite fast and had more leaf area than those in the open field. These plants were more sensitive to drought during a dry spell in June. Nearly all the millet growing under the trees died, while that in the open field survived and produced a reasonable grain yield. This is in contrast to what happens in most years, when millet grown under *Faidherbia* trees produces more than millet grown in the open field.

These findings have important implications for the development of farming systems in the Sahel where subsistence farmers aim to minimize risks, and achieve yield stability. The risk-reducing aspects of soil and crop growth variability and of practices such as intercropping long- and short-duration varieties are important considerations in the analysis of existing farming systems and in the design of new ones.

Little Things Can Help a Lot

Soil microarthropods are tiny creatures that inhabit the surface layers of the soil. They play an important role in maintaining soil structure and fertility. It has been shown that the greater the population of microarthropods in Alfisols, the better is the

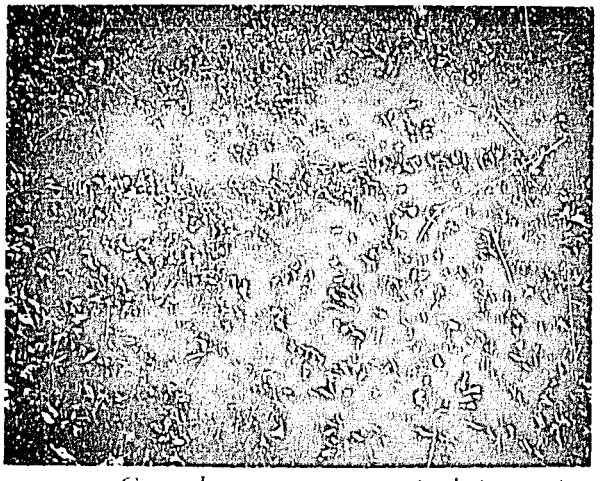
soil structure, with reduced runoff and soil erosion. Soil management practices affect microarthropods, but their impact in SAT agroecosystems needs to be better understood. Population counts of these tiny creatures could possibly be used as a measure of the impact of soil management practices on sustainability.

In an experiment on an Alfisol at ICRISAT Center, microarthropod population densities and functions are being evaluated for a range of soil management practices. Results from the first three seasons indicate that when a soil is covered by a perennial crop it harbors more arthropods than a soil that is cropped with an annual each year. In soils that were not tilled, left bare, or mulched with rice straw there were more microarthropods than in tilled soil. Soils that were tilled and mulched with rice straw had more arthropods than unmulched tilled soils. In all the treatments, microarthropod densities were significantly higher in the rainy season than in the dry season. Population densities were significantly reduced when carbofuran, an insecticide used to control shoot fly was applied, but recovered within about a year. In 1992 maize was sown in all the plots that had received different soil management treatments. The highest yields were achieved from plots previously under perennial crop cover.

On the plots that were mulched with rice straw, most of the straw disappeared during the year, primarily as a result of fragmention by microarthropods. As the decomposition progressed the concentrations of total nitrogen and potassium in the decomposed straw were also influenced by the population densities of the microarthropods. Tillage, microarthropod densities, and straw moisture had synergistic effects on the mineral nutrient concentrations in the straw mulch during the process of decomposition.

Extending the Frontiers in Drought Research

Because its evaporative demand is high, water-holding capacities of soils are low, and rainfall is unpredictable, groundnut yields in the SAT can be severely reduced by drought. This reduction can be as high as 30-60% depending on the time the drought occurs, its intensity, and duration. Supplemented irrigation is only feasible on a small portion of the arable area in the SAT. Groundnuts that can escape, tolerate, or avoid severe water deficits would improve long-term crop productivity in drought-prone environments.



Groundnut genotypes vary in their reaction to drought stress.

Genotypes with drought tolerance could be bred more easily if the physiological basis of genotypic performance under drought conditions was understood. Reliable traits for drought tolerance in germplasm need to be identified and combined through breeding, to develop the best-adapted genotypes.

Water-use efficiency, defined as total dry matter production per unit of water transpired, is an important parameter that can influence a genotype's performance in drought conditions. This is not an easy trait to measure on a large scale because techniques to accurately measure transpiration and root mass under field conditions are not available. However, recent ICRISAT collaborative research with the Australian Centre for International Agricultural Research (ACIAR) has shown that the carbon isotopic composition in groundnut leaves is well correlated with water-use efficiency, and could be used as a basis for selection. Further research showed that leaf carbon isotopic composition is also well correlated with leaf thickness. This characteristic could be used as an even more rapid and inexpensive basis for selection for water-use efficiency. Unfortunately, plants that used water efficiently did not partition dry matter to pods well.

Aerial view of groundnut drought-screening trials at ICRISAT Center.

During 1992, 256 germplasm accessions were grown under irrigated conditions, and screened for water use and partitioning efficiencies using a novel, non-destructive technique developed by ICRISAT scientists. There was significant variation within and between the botanical groups; virginia runner and virginia bunch types generally had thicker leaves than spanish and valencia types. This suggests that virginia runner and bunch types should be used to improve water-use efficiency. The spanish and valencia types were superior in dry matter partitioning. The selected genotypes are being further examined for performance under drought conditions.

A collaborative project involving ICRISAT, ACIAR, and the Indian Council of Agricultural Research will be initiated in 1993 to determine whether it is possible to select for water-use and dry matter partitioning efficiencies in groundnut. This project will also test the stability of these traits in selected genotypes across a range of environments in India.

Improving Selection Methods for Stressed Environments

Monitoring the microclimate in a groundnut crop at ICRISAT Center.

If superior groundnut genotypes that match specific target environments are to be identified, it is necessary to find out how genotypes, environments, and their interactions affect yields. This is usually done by conducting many multilocational trials, but at the ICRISAT Sahelian Center the use of crop models instead is under investigation. Success should significantly improve the cost efficiency of selection. This is particularly important in the Sahelian environment where the large amount of field or spatial variability requires extensive amounts of expensive replication both within sites and across years. The model being tested defines yields as the product of three parameters (crop growth rate, the duration of reproductive growth, and partitioning of assimilate to reproductive growth). It is testing the hypothesis that genetic effects are principally associated with partitioning, and that crop growth rate effects are mainly attributable to environmental effects.

The model has been used to identify superior groundnut genotypes for the Sahelian Zone of western Africa. Earlier research showed that genotypes adapted to this Zone can be identified by the yields they produce during the hot summer season, if the water supply is adequate.

To test the new method 625 groundnut genotypes were grown at the ICRISAT Sahelian Center in the 1991 hot season, and the contributions to their yields from the three model parameters determined. For two separate trials in 1992, contrasting genotypes were selected and re-evaluated for both their partitioning (the model parameter) and yield.

At ICRISAT Center, when the same model was earlier used for drought screening, and at the ICRISAT Sahelian Center the correlation of genotype yield between years in screening trials was low, primarily due to the inconsistency of the crop growth rate component; while the correlations for partitioning were very satisfactory. Thus, using the model improves the reliability of identifying superior genotypes, and allows more material to be screened for both drought and heat tolerance without using additional resources. It could prove very useful to breeders; and save a considerable amount of time and money.

Modeling Production Potential

Taking groundnut crop measurements to validate a computer model.

A computer model that simulates groundnut growth is being used to estimate production potential and yield stability under optimal crop management practices, for weather conditions and environments representing different groundnut-growing areas in India. The model could be used to find out which locations have the potential to produce better crops, and will help scientists to focus their research.

ICRISAT and the Indian national program have worked together to test, validate, and modify PNUTGRO, a groundnut model developed by the University of Florida. As a result, PNUTGRO can now account for 71% of the variability in biomass yield, 84% in pod yield, and 85% in seed yield of groundnut caused by weather variations, particularly rainfall.

Using PNUTGRO, data on site-specific soil characteristics, and historical weather records, the production potential of a groundnut cultivar was estimated at five groundnut-growing locations: Hisar, Anand, Patancheru, Anantapur, and Coimbatore. These locations vary in their rainfall quality and intensity, and in the types and depths of their soils.

PNUTGRO shows that if adequate water is available, Anand, Patancheru, and Hisar have greater potential for groundnut production than Coimbatore and Anantapur, and could produce up to 4.4 tons of groundnut pod per hectare. Results further suggest that Anand and Patancheru have the greatest potential for groundnut production, because yields are reduced at Hisar by lack of water during the reproductive growth phase, and at Anantapur and Coimbatore when drought occurs during both vegetative and reproductive phases.

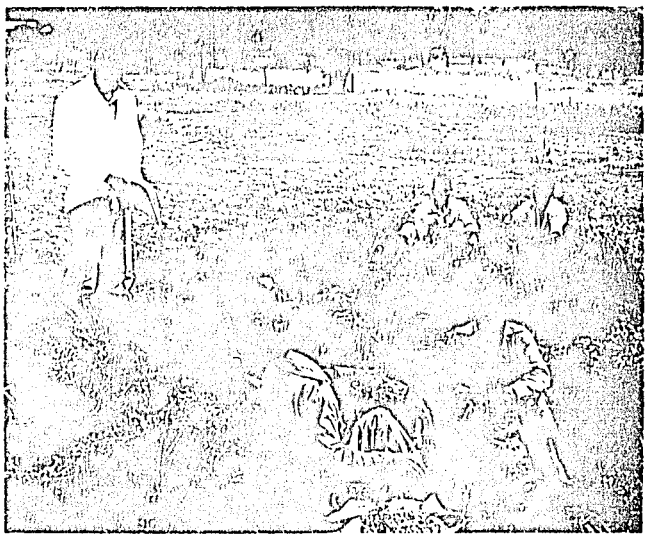
This information will help researchers to make specific selections for the groundnut types best-adapted to these particular constraints, and will avoid extensive costly screening trials.

Breeding Groundnuts to Beat the Drought

In Botswana, the rainy season often lasts for more than 120 days, but total rainfall is low. Night temperatures during the rainy season are also low. In contrast, northern Namibian rainy seasons are short, seldom lasting more than 90 days. SADC/ICRISAT

staff working with the Groundnut Project based in Malawi and funded by the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) are collaborating with scientists in the national programs of these countries to develop groundnuts adapted to their environments.

At Sebele Research Station, Botswana in a drought year, when the total rainfall was only 200 mm, it was possible to select more than 500 plants that produced viable seeds. Some plants flowered after only 26 days. The 144 plants that produced the highest pod yields will be grown at Chitedze Agricultural Research Station, Malawi; and those that flower early and yield well will be returned to Botswana for further selection.

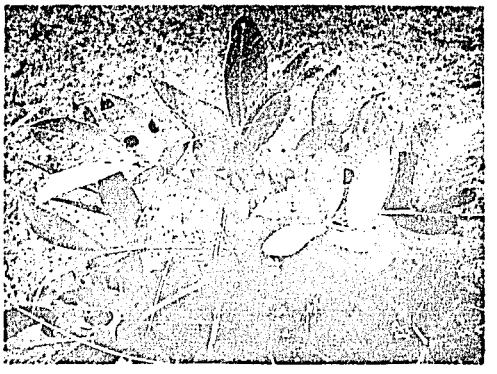


Harvesting groundnut trials at Chitedze Agricultural Research Station, Malawi.

In northern Namibia, national program scientists have determined the optimum season length of spanish-type genotypes. When 20 selected spanish genotypes were grown under irrigation at Mahanene Research Station, some of them took only 82 days to mature, whereas the same genotypes took 116 days to mature at Chitedze. Populations selected in Botswana are also being tested in Namibia. The combined efforts of the two national programs and the SADC/ICRISAT Project are thus making progress in identifying groundnuts that can grow and produce crops in these very dry regions.

Relationships Between Plant Populations and Foliar Diseases Resistance

Foliar diseases are a major constraint to groundnut production in western Africa. They reduce yield by reducing the active leaf area available for photosynthesis. Early and late leaf spots, and rust are the most common diseases in the region, where they can cause yield losses between 10 and 70%. Disease incidence and severity vary with location, and are governed by a complex set of genetic and environmental circumstances. At low plant populations the micro-climate within the crop canopy does not favor disease development, and agronomic evidence suggests that yields are maximized.



Leaf spot diseases can reduce groundnut yields by 70% in western Africa.

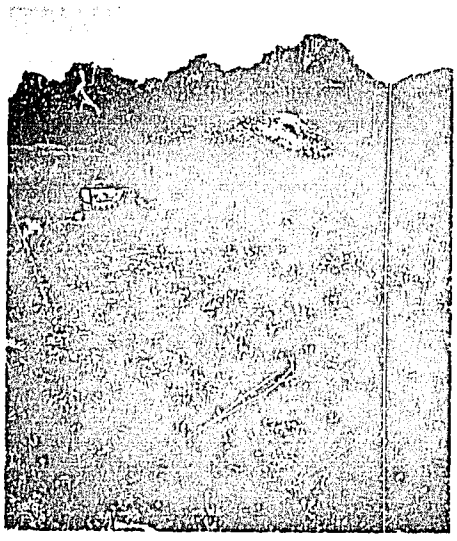
However, if other factors such as the use of rotations and/or fungicides which limit disease development are introduced into crop management, then the basic physiology of yield maximization may change. Therefore, it is necessary to re-evaluate the basic agronomic practices to find out how they are influenced by disease pressure and control measures.

At Bengou, Niger where, in the 1992 rainy season, late leaf spot was the major foliar disease, two susceptible and two resistant groundnut genotypes were tested in high (natural) and low (fungicide-protected) disease pressure environments.

Fungicide application significantly increased the pod yields of all genotypes, and the highly significant interaction between fungicide spray and plant population confirmed that practices which modify disease pressure require the re-evaluation of other agronomic factors. This trial also showed that ICRISAT breeding lines with either resistance to foliar diseases, or with higher yield potential are useful in western Africa. Even without fungicide they can produce higher yields than local genotypes, and respond positively to higher plant populations. This trial series will be expanded to confirm assumptions about the interactions between rotations and population. The research should lead to higher adoption of improved technologies by farmers, since the importance of changing both variety and management together is being established.

Conquering Groundnut Iron Chlorosis

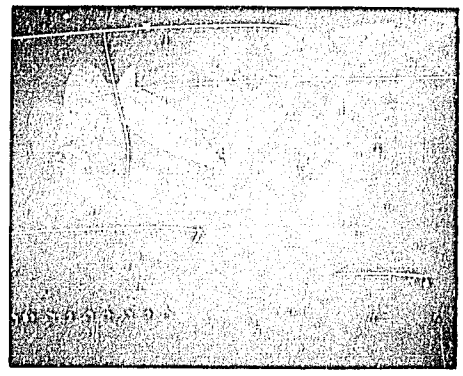
Iron chlorosis is a constraint to groundnut production in many parts of the world, but little quantitative data exists on the actual yield losses it causes in the Indian SAT. Current research at ICRISAT Center combines studies of farmers' perceptions and management practices affecting iron chlorosis in groundnut, with follow-up research to quantify yield losses and identify management practices related to the problem.



Iron chlorosis can severely deplete groundnut yields.

Initial diagnostic village surveys in two Indian states indicated that iron chlorosis exists in many areas, and that the problem is mainly associated with irrigation, the variety of groundnut grown by the farmer, and fertility management. The problem is severe in calcareous black cotton soils where canal irrigation is used. Farmers often mistake the symptoms for nitrogen deficiency, and try to cure them by applying high doses of fertilizers. Farmers estimate groundnut yield losses to be between 10 and 25%. Where crops have failed because of iron chlorosis farmers have stopped growing groundnuts in favor of such iron-efficient crops as sunflower.

Yield losses have now been quantified in pot studies, and in on-station and on-farm collaborative trials with the Central Research Institute for Dryland Agriculture (CRIDA) in the two Indian states where surveys showed that the problem is severe. The pot studies confirmed that waterlogging is a major factor in the development of iron chlorosis, and that symptoms increase with increasing levels of applied nitrogen. All the groundnut varieties tested, both local and improved, were found to be highly susceptible.



Symptoms of groundnut iron chlorosis.

ICRISAT studies have shown that iron chlorosis can be alleviated by; sowing groundnut on raised beds, applying foliar sprays of 0.5% iron sulfate, or growing ICGV 86031. This iron-efficient genotype is capable of producing 15% higher pod yields than the local cultivar, and almost a ton more fodder per hectare in farmers fields in an area where iron chlorosis causes serious problems.

Long-term Component Study of Vertisol Watershed Technologies

Two areas of research are the focus of the current long-term trials of Vertisol technologies at ICRISAT Center. First, because farmers seldom adopt complete management packages, increased knowledge of the performance of individual components and of their interactions is sought. Second, to better understand the sustainability of these technologies, trials are long-term in nature and include the participation of a multi-disciplinary team of researchers. The plots used in this study are replicated and are used to compare fertility (chemical fertilizers vs. farmyard manure), genotype (traditional vs. improved), land form (broadbed-and-furrow vs. flat), and water availability (irrigated vs. rainfed).

Results from the three seasons (1989-91) appear to indicate that land form treatments have little effect on plant growth and yield. A traditional postrainy-season sorghum genotype showed significant yield differences between land forms in 1989 but no differences by 1990 and 1991. This same trend was found with an improved sorghum hybrid and with legume crops. It so happens that the plots used for broadbeds and furrows for all crops had previously received fertilizers; this was not the case with the plots used for flat land forms. Preliminary soil tests indicate that this could explain the difference between the results of the first year and those of the following two years.

For the non-legume crops, fertility differences have had the most striking effects; for legumes, no consistent treatment differences for fertility have yet been introduced.

Vertisol watersheds at ICRISAT Center where long-term cropping systems and fertility studies are in progress.

Results suggest that further work is needed on integrated fertility management, particularly on the effects of rotation components on soil fertility both in the long- and short-term. It may also be significant to learn at which point in the rotation cycle fertilizer applications are most beneficial.

Irrigation results to date are inconsistent; an apparent lack of response to irrigation in postrainy-season sorghum may be attributed to this species' ability to extract residual moisture from a saturated Vertisol profile. Improvements in production were evident when irrigation was combined with increased fertility levels on sunflower and safflower. These cash crops derive the most benefit from supplementary irrigation.

For the postrainy-season traditional sorghum genotype, disease increased with increasing fertility. This relationship may affect farmers' adoption of improved management practices on traditional genotypes.

Rotations appear to be a good strategy for controlling nematode and disease problems. Soil nematode populations increase significantly following crops of pigeonpea or

sunflower. Placing these species in a rotational sequence where they are preceeded or followed by sorghum, pearl millet, or maize, reduces damage when the crop appears again in the rotation cycle.

Ultimately, this study will provide an identification of long- and short-term production constraints resulting from changes in management.The study will also assist researchers to develop measures of sustainability that can be applied to other areas. Farmers will benefit because technologies passed to national research systems for dissemination will have been rigorously tested in a 'systems' manner before release.

Collaboration in Ethiopia

ICRISAT is working with the International Livestock Centre for Africa, the Institute for Agricultural Research, and Alemaya University of Agriculture in Ethiopia to develop strategies and technology options to raise and sustain crop and livestock production on Vertisols.

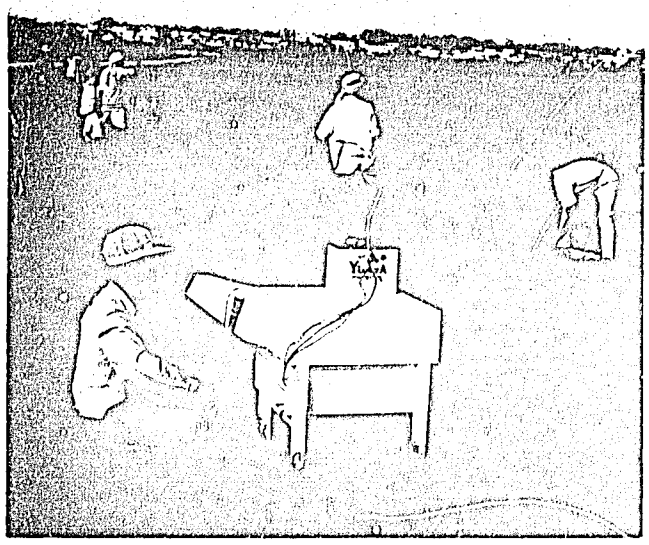
It is now recognized that the broadbed-and-furrow technique developed by ICRISAT may be widely adopted in some Ethiopian Vertisol areas. During 1992, a private manufacturer in Addis Ababa started to make attachments for the local plow that will enable it to form broadbeds and furrows.

In collaborative trials perched water table fluctuations in experimental plots at Ginchi and Akaki were characterized. Measurements showed that, during the rainy seasons of 1991 and 1992, the perched water table was within 30 cm of the ground level at certain times, thus exposing crops grown there to the risk of waterlogging. An analysis of wheat yield data from Ginchi and Akaki showed that yields were significantly higher from crops grown on 26-cm high broadbeds than on beds made to the standard specifications of 13 cm. This suggests that the height of broadbeds constructed at a particular site should depend on the intensity of the risk of waterlogging.

Measuring the height of the water table on a Vertisol in Ginchi, Ethiopia.

Watching them Grow

At ICRISAT Center, scientists working on a special project under the auspices of the Government of Japan use a 'minirhizotron' to monitor the rates at which chickpea roots grow when they are subjected to drought. The scientists dug a series of holes in



Studying chickpea roots with the help of a 'minirhizotron' at ICRISAT Center.

trial plots into which long transparent glass tubes were inserted into the ground at an angle of 45°, with the above-ground portion painted black to prevent light entry. At regular intervals, a customized video camera was inserted into the tubes to monitor root growth. Conventional 'destructive' methods result in the death of each plant inspected. With the minirhizotron technique, the roots are not damaged and the plants are not killed; so root systems can be continuously observed. Five chickpea varieties and 15 video stations were used in an experiment to identify chickpeas with large, deep root systems that can best absorb moisture in black, clayey soils when water supply is limited.

This innovative technique has also been used to record the root dynamics of pigeonpea, including its root formation, and root death after temporary waterlogging. This experiment led to the discovery of a consistent relationship between pigeonpea rooting profile and soil depth. Daily changes in root length density, and differences between waterlogged and non-waterlogged roots were observed. Roots which had suffered from waterlogging recovered, with root length densities increasing faster than for non-waterlogged roots during the recovery process. The observations also showed that after waterlogging roots nearer the surface recover before those deeper in the soil.

This technique has proved its value for monitoring root growth under two extreme conditions, drought and waterlogging. The minirhizotron can be used not only to measure root length, but also to observe such features as thickness and branching frequency. The true picture of what is happening under the soil's surface can represent vital information for studies on water and nutrient uptake by plants. Underground movies can have real scientific value!

Improving Pigeonpea in Southern Africa

Presently, pigeonpea is in high demand in Malawi. Several organizations including those working with refugees, and in education and health, are looking forward to increased pigeonpea production as it provides a valuable source of dietary protein. Small-scale farmers could grow short-duration pigeonpea in areas which face erratic

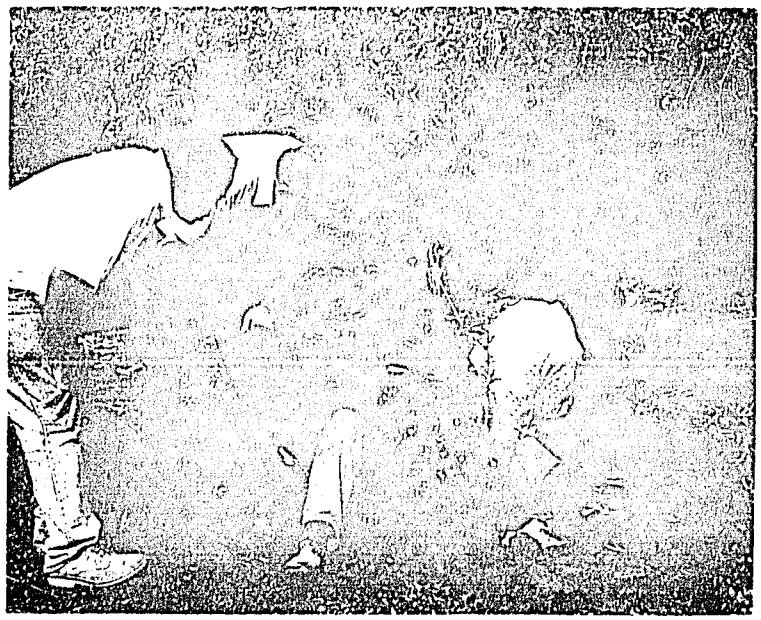
or insufficient rainfall; particularly in years when the rainfall comes late. On commercial farms short-duration pigeonpea could fit well into rotations with other crops and has the additional advantage of being mechanically harvested.

Although long-duration pigeonpea has been cultivated in Malawi for a long time, the introduction of short-duration pigeonpea is recent. Research started in 1986 with the introduction of genotypes from ICRISAT Center. After extensive testing at three locations, three short-duration genotypes are currently being evaluated for consumer acceptance by the national Adaptative Research Team, and for grain yield at 28 locations. Over 40 other lines are being evaluated at several locations for adaptability, grain yield, seed size, and seed color.

The ICRISAT Pigeonpea Project based at Chitedze Agricultural Research Station was started in January 1992 to improve the productivity of pigeonpea in southern African countries. The project is funded by the African Development Bank and implemented by ICRISAT.

Late in January 1992, 34 germplasm and 20 promising pigeonpea lines from the Malawi national program were sown at Chitedze, in a preliminary observation nursery. Although sowing was very late, 75 crosses were made and 300 individual plants selected. From the same nursery 20 entries were selected for future evaluation in the SADC region.

A further 216 germplasm and advanced short-duration breeding lines were sent to project collaborators in Malawi, Mozambique, Namibia, Tanzania, and Zambia to be evaluated in the 1992/93 cropping season.



Crossing pigeonpea at Chitedze Agricultural Research Station.

Pigeonpea in Sri Lanka

In Sri Lanka the Department of Agriculture/ICRISAT collaborative project on pigeonpea development that is funded by the Asian Development Bank received a boost this year when ICRISAT's Deputy Director General toured the country at the

Discussing collaborative pigeonpea trials in Sri Lanka.

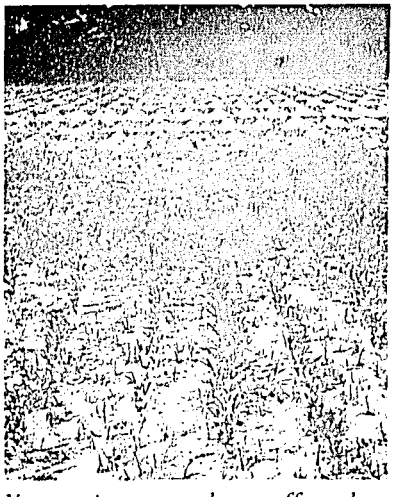
invitation of the Director of Agriculture, to review ongoing pigeonpea work in the Asian Grain Legumes On-farm Research (AGLOR), and other collaborative projects, including those of the Cereals and Legumes Asian Network (CLAN).

During their visit, ICRISAT staff met the Minister of Agriculture, Development, and Research, who showed great interest in extending the cultivation of pigeonpea in an effort to reduce the country's lentil imports. He promised ICRISAT the financial and administrative support needed to extend the crop to the 'intermediate' and 'dry' zones of Sri Lanka.

It was evident that the people of Sri Lanka whom ICRISAT staff met during their extensive tour welcomed the availability of pigeonpea *dhal*, and that farmers and research and extension scientists are optimistic about the crop's success.

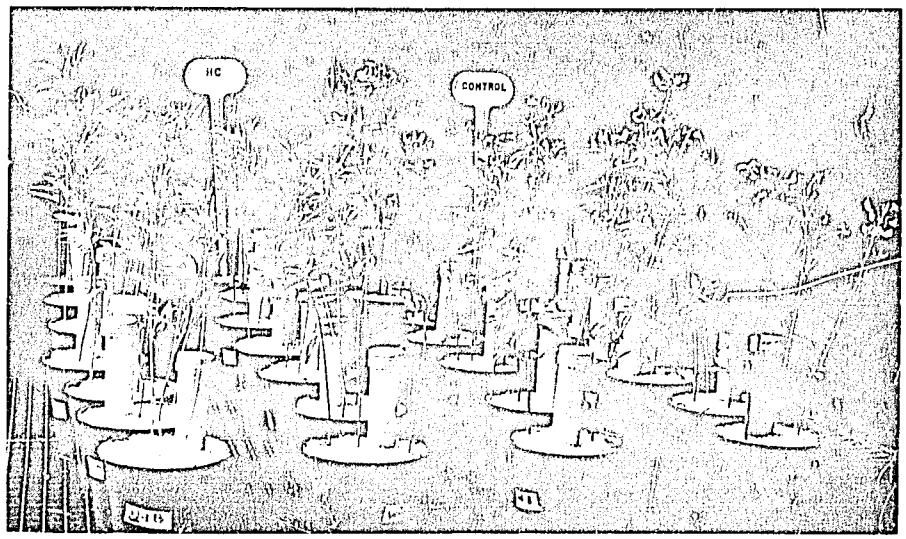
Identifying Pigeonpea's Unseen Enemies

Symptoms of nematode infection are subtle and difficult to distinguish from those of other pathogens. These tiny worms are hard to detect, even when they are present in large numbers. Nematode damage to pigeonpea is not dramatic but sure and cumulative. On a global basis, it is estimated to reduce pigeonpea yields by over 13%. An initial density of 3.0 nematodes/cm^3 soil can cause a 25% reduction in pigeonpea biomass. The root-knot, cyst, and reniform nematodes are the most important species affecting pigeonpea; they are all root parasites. Root-knot nematode infection makes pigeonpea less able to resist the fungus that causes fusarium wilt disease.



Young pigeonpea plants affected by soilborne nematodes.

Now, easy methods of nematode detection have been developed. Reniform nematodes produce mucilaginous egg sacs on pigeonpea roots. Soil particles stick to these egg sacs and are not easily dislodged when the roots are shaken. If these 'dirty roots' are dipped in 0.25% trypan blue stain and rinsed in water, the nematode egg sacs are selectively colored blue, while the roots are not stained.



Screening pigeonpeas for resistance to nematodes in a greenhouse at ICRISAT Center.

Root-knot nematodes reproduce rapidly, producing large numbers of egg sacs that can also be stained with trypan blue to increase their visibility.

Very few efforts have been made to evaluate pigeonpea cultivars or germplasm for resistance to nematodes because standardized resistance screening methods were not available. At ICRISAT Center, simple and reliable greenhouse resistance screening procedures have now been developed. Screening showed that pigeonpea cultivars, including commercial cultivars, are generally susceptible to nematodes.

Nematicides are very expensive and the availability of resistant cultivars would help resource-poor farmers to effectively reduce damage to their crops. Recent attempts to identify resistance genes revealed that wild species of pigeonpea in the ICRISAT gene bank have resistances to all the three types of nematodes, and that some have resistance to more than one nematode species. The identification of these valuable sources of resistance highlights the value of collecting and conserving not only cultivated species, but also their wild relatives.

Conventional breeding methods have not been successful in obtaining fertile crosses between wild and cultivated pigeonpeas. However, such modifications to hybridization techniques as the use of hormones, or the rescue of ovules and hybrid embryos by tissue culture could be successful in transfering useful genes from the wild species.

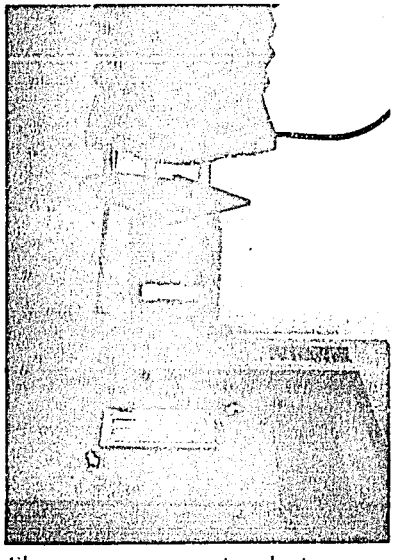
Another hope of control lies with three species of fungi that are commonly found parasitizing eggs and females of the cyst nematode. Their use as possible agents for biological control is being investigated at ICRISAT Center.

In areas where nematode damage incurs serious crop losses, changing cropping patterns may help to reduce the problem. Population densities of the cyst nematode increase more rapidly on sorghum/pigeonpea than on other intercrops. Sunflower is a very good host of the reniform nematode, hence avoiding its use in intercrops could help farmers reduce pigeonpea losses.

Mapping Downy Mildew Resistance Genes in Pearl Millet

Downy mildew continues to be the most devastating disease of pearl millet in the SAT areas of Asia and Africa. Host plant resistance offers the best means of containing this disease, but because the pathogen is variable, such resistance often breaks down, particularly in single-cross pearl millet hybrids.

Downy mildew disease can destroy pearl millet heads.



Fluorescence screening during gene-mapping studies.

Through a collaborative International Pearl Millet Downy Mildew Nursery (IPMDMN), resistant lines identified at ICRISAT Center are evaluated at 'hot-spot' locations in India and western Africa to identify lines with stable resistance across pathogen populations and environments. During 1989 to 1992, 419 pearl millet accessions from Zimbabwe were screened in the IPMDMN. Two of these lines were resistant at ICRISAT Center, Aurangabad, Mysore, Jamnagar and Bhavanisagar (India), Bengou (Niger), and Cinzana (Mali). These are the first sources of downy mildew resistance that ICRISAT has identified in breeding material originating from Zimbabwe.

Resistance to downy mildew in several lines is known to be dominant and is thought to be governed in part by major genes. Resistance has been successfully transferred to inbred lines and resistant hybrids have been produced.

In two ODA-funded collaborative projects between ICRISAT Center and two laboratories in UK, one at the University College of North Wales, Bangor and the other at the Cambridge Laboratory, Norwich, genetic markers have been identified for the genes contributing to resistance in two pearl millet lines that are representative of the Indian and western African populations of the pathogen.

Using the genetic markers the pearl millet downy mildew resistance genes are being mapped in the UK. It may be possible to identify and map resistance genes for individual isolates of the pathogen. This would facilitate breeding genotypes with resistance genes for several isolates. Such genotypes would be useful in both India and western Africa.

Several chlorophyll-deficient pearl millet mutants have been identified amongst the ICRISAT gene bank accessions. These have been purified and tested for their reaction to downy mildew. Six lines are highly resistant, and will be useful in future attempts to map resistance genes.

Solving Finger Millet Problems

Before investing resources in studying the diseases of finger millet, scientists based at the Eastern Africa Regional Cereals and Legumes (EARCAL) program in Nairobi went to the farmers of the region to find out which diseases cause the most problems. In January and February they surveyed nearly 300 farmers' fields in southwest Uganda, and western and eastern Kenya. In 272 of these fields they found finger millet crops suffering from neck and finger blast disease. The same fungal pathogen also attacks finger millet leaves, but the foliar phase of the disease was only severe in 33 fields. Finger millet also suffers from four of five other diseases but none of these was so severe or damaging as blast.

Based on these findings ICRISAT scientists developed a simple field technique to screen finger millet germplasm lines for resistance to blast disease. The essential components of the technique are the use of infected finger millet debris to provide the fungal inoculum, and irrigation to create a humid environment that is favorable for infection and disease development.

After testing four treatment combinations during the 1991/92 short rainy season on four blast-susceptible and two blast-resistant finger millet germplasm lines, they found that the irrigation × infected debris treatment combination was the most effective.

Using this technique EARCAL scientists screened 1000 finger millet lines from ICRISAT Center gene bank, 273 from SADC/ICRISAT SMIP, and 129 germplasm lines from the national program in Uganda. From all these lines they identified 121 with good levels of blast resistance and desirable agronomic characters. These lines will be used to breed genotypes resistant to the most serious disease threatening finger millet crops in eastern Africa.

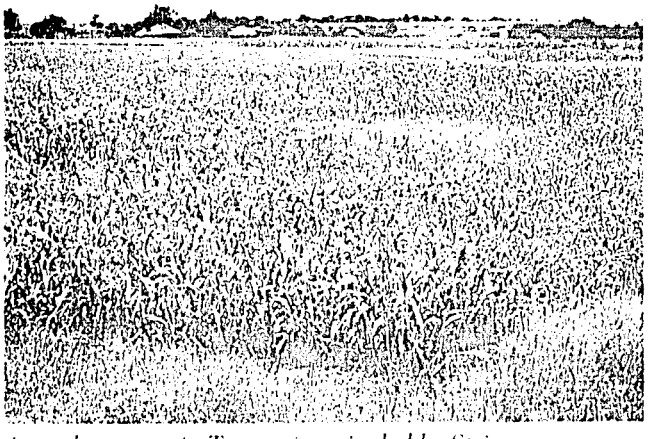
ICRISAT scientists are working on the blast disease that reduces yields of finger millet in eastern Africa.

Combined Efforts in Tanzania

ICRISAT's links with Sasakawa Global 2000 agricultural development programs have considerably enhanced and facilitated travel and interaction with the national program in Tanzania. The breeder and entomologist from SADC/ICRISAT SMIP, two national scientists, and the National Coordinator of Global 2000 made a joint 10-day tour of

Tanzania to evaluate the sorghum crop. They visited research stations, demonstration fields of four sorghum varieties in the prerelease stage, and crop management training plots in farmers' fields. Two of the varieties they saw doing well were bred by ICRISAT and have been recommended for release by Tanzania in the 1992/93 cropping season.

During the year a survey was conducted in the central and northern areas of Tanzania in collaboration with Long Ashton Research Station, Bristol, UK and the Tanzanian national program. The parasitic weed, *Striga* is widespread in the surveyed areas; two species that parasitize maize and sorghum, and one that attacks sorghum, all cause economic losses. Each *Striga* species occupies different geographic niches, some of which overlap. This means that there are different biotypes of the various species of *Striga*, and that each causes problems in a particular geographic area, emphasizing yet again how difficult it is to find a solution to this devastating problem. Seeds of these host-specific *Striga* biotypes were collected and characterized at Long Ashton during the 1992/93 cropping season. Information derived from these cooperative research efforts will be used to devise control measures for this pernicious parasitic weed. Long Ashton scientists are also working on *Striga* with the International Institute for Tropical Agriculture (IITA) in an Africa-wide effort to develop control measures.



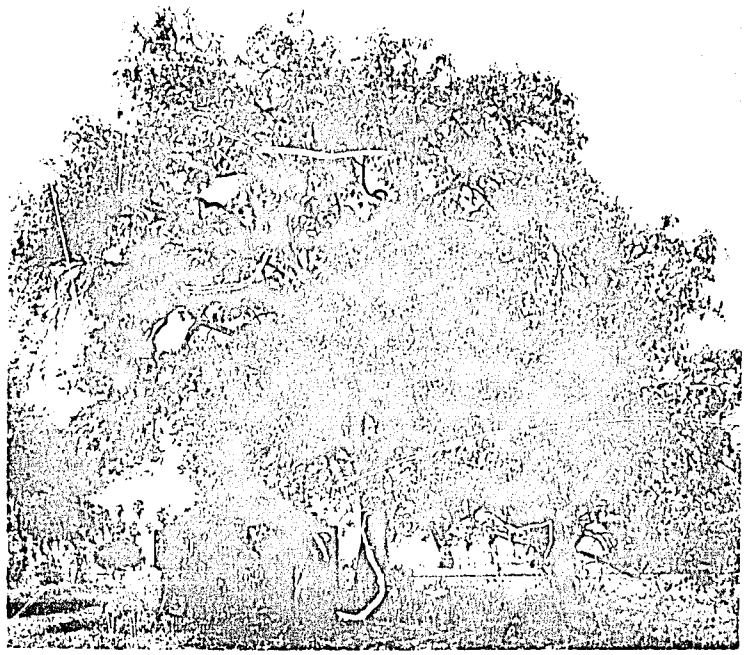
A sorghum crop in Tanzania, crippled by Striga.

Biological Insecticides

Neem trees are common in the SAT where neem is traditionally used to make medicines and control insects. In collaborative studies with the Indian Institute of Chemical Technology different solvent systems were used to extract a biologically active fraction from neem seeds. The extract mainly acts as an antifeedant towards insects, and at low concentrations disrupts insect growth. It was found to be effective against several insect pests of soghum including the spotted stem borer, oriental armyworm, gray weevil, and head bugs. Application of neem extract under field conditions resulted in a 30% increase in grain yield over unprotected crops, and pest control was comparable to that provided by a commercial insecticide. An added advantage of neem extract is that it has no adverse effects on beneficial insect species.

Another common plant in the SAT is the custard apple from whose seeds a biologically active fraction containing acetogenins has been isolated. Acetogenins are highly toxic to insect pests. In laboratory and field trials, custard apple extract has been found as effective as endosulfan, a commercial chemical insecticide, for the control of spotted stem borer, armyworm, and head bugs.

Efforts are now in progress to formulate these plant extracts as biopesticides that could be used as alternatives to synthetic insecticides, thereby minimizing deleterious effects on the environment, and the problems of insect resistance.

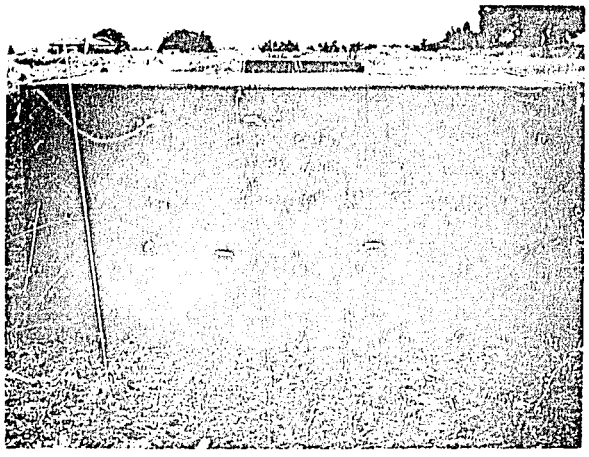


Neem tree seeds contain an effective biological insecticide.

Controlling Shoot Fly

The principle of plant resistance to insects takes into account the natural ability of plants in any ecosystem to resist or tolerate pest attacks, and to reduce their populations. Major advantages in the genetic manipulation of host plant resistance in cultivated crops are that it requires practically no input from the farmer, and does not harm the environment.

Initial efforts at ICRISAT to screen sorghum for resistance to shoot fly were greatly enhanced by access to the large germplasm collection of over 30 000 accessions, and a wide range of test locations in India and Africa. Several resistant landraces were identified, but breeding for resistance using these landraces initially resulted in only marginal genetic improvement in agronomically improved cultivars. Concerted efforts by breeders and entomologists, however, have resulted in the identification of resistance mechanisms and several associated factors. Several genes are known to confer resistance to shoot fly. Although this knowledge is of prime importance for progress in breeding for resistance, it became clear that a multi-pronged approach was necessary against an insect pest that causes an annual loss in sorghum production worth over $200 million in India alone!



Cages used to screen sorghum seedlings for resistance to shoot fly.

Over 340 wild sorghums were evaluated for resistance using a special cage technique that ensures uniform infestation and precise evaluation of test entries. Four accessions with very high levels of resistance were identified. Useful genes from wild sorghums were introgressed into cultivated sorghums and the crosses obtained have been selected and advanced under critical evaluation through five or six generations. Several progeny have maintained their resistance levels and are now being evaluated for use in the development of improved high-yielding, shoot fly resistant cultivars.

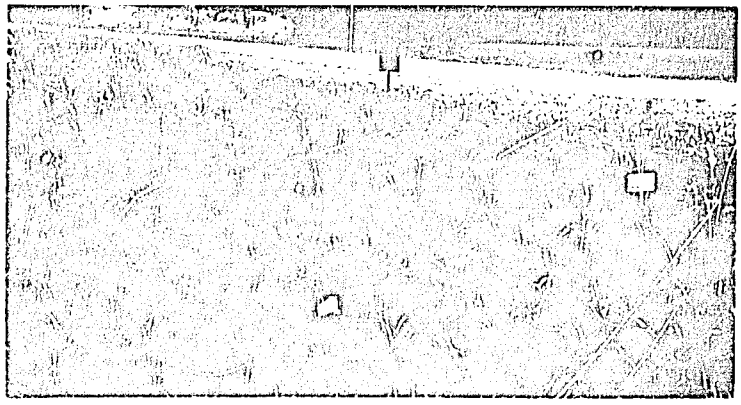
In another study, the relationship between several resistance factors and grain yield is under investigation to determine their compatibilities and their interactive roles in the expression of resistance and grain yield potential. In the process it was found that the expression of several factors that are linked to resistance differ between tall and dwarf sorghum genotypes.

From earlier attempts to increase the level of resistance in the existing random-mating sorghum population, it was found that the levels of variability in resistance and agronomic desirability were both low. It is advantageous to have high variability for these characters so the population has now been diversified by introgressing new sources of resistance, and the first random matings were made in the 1992/93 post-rainy season. This should result in the 'pyramiding' of resistance genes within the population, and permit the development of lines with higher levels of resistance than those currently available.

One of the factors identified by entomologists as associated with sorghum resistance to shoot fly is the wetness of the central whorl leaf of seedlings, or leaf surface wetness. An interdisciplinary team working at ICRISAT Center has found that leaf surface wetness is affected by the amount of water in the soil, and not solely governed by the internal plant water status. They also found that the mechanism by which water is transferred to the leaf surface in susceptible genotypes appears to be lacking in resistant ones. Biochemical studies have revealed the existence of a 'barrier' within the leaf structure of resistant genotypes which interferes with a physiological process in the movement of water onto the leaf surface.

While these findings could increase the level of resistance to shoot fly through genetic manipulation, scientists hypothesized that if soil moisture in irrigated sorghum fields were reduced during the first 4 weeks of crop growth when seedlings are

most prone to shoot fly attack, damage could be reduced. Trial results confirmed they were right. Under shoot fly infestation, plots of a commercial sorghum hybrid that received only 55 mm irrigation/ha during the first 4 weeks yielded twice as much as control plots that received over 120 mm/ha during the same period. Even when there was no shoot fly infestation, sorghum with reduced irrigation yielded 3 t/ha, compared to the yield of 2.5 t/ha by that in fully irrigated control plots. This management strategy is not only relevant to India where shoot fly is endemic, and approximately 525 000 ha of irrigated postrainy-season sorghum are grown, but also to non-endemic countries like Sudan where over 4.5 million ha sorghum are irrigated. The amount of precious irrigation water saved and available for other uses is an added bonus.



The sorghum plants in the background received less irrigation than those in the foreground and were not damaged by shoot fly.

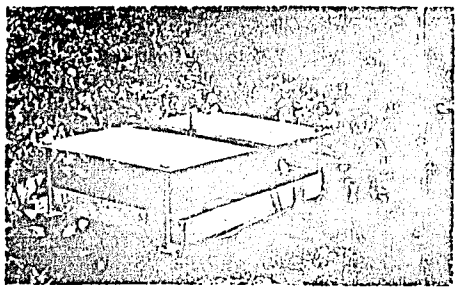
Managing Legumes Pests

Surveys and on-farm trials are a prelude to developing pest management strategies. Groundnut insect pest surveys in India organized during the 1991/92 postrainy season clearly demonstrated that soil insects affect groundnut production. In general, groundnut farmers in the surveyed areas are aware that pests damage their crops, but make no attempt to control them.

Artificial screening techniques developed by ICRISAT scientists to screen groundnut lines against leaf-eating caterpillars have been successfully evaluated by testing 36 pest-resistant groundnut lines in a replicated trial at ICRISAT Center. By releasing 100 000 artificially reared *Spodoptera* larvae on the test rows at a rate of 1 larva/plant when the seedlings were 40-days old, a high level of defoliation was established. Using this technique entomologists identified five ICRISAT-bred lines with promising resistance to *Spodoptera* and jassids that can yield more than 2 t/ha during the rainy season. Groundnut entomologists working in the All India

Field screening technique used to assess Spodoptera *damage in groundnut.*

Coordinated Research Project on Oilseeds (AICRPO) are aware of this technique, they also screen genotypes for resistance to these pests at 'hot spot' locations where natural infestation levels are high.



A trap used to monitor groundnut leaf miner populations.

A collaborative study with the Natural Resources Institute (NRI), UK, a sex pheromone that can be used to monitor populations of the groundnut leaf miner. Further studies with this pheromone showed that water traps are the most effective monitoring device when positioned 0.5 m above ground level.

Monitoring insecticide resistance in the pod borer, *Helicoverpa armigera* has advanced significantly during the past year with the introduction of a technique that provides a rapid-means of assessing insecticide resistance in field-collected insects. Weekly changes in resistance to pyrethroid, organophosphate, and cyclodiene insecticides are currently being monitored at four locations in Andhra Pradesh. An Australian agrochemical organization, the Insecticide Resistance Action Committee provided funds for a visiting technical officer to assist the NRI/ICRISAT project. This additional support made it possible to extend the resistance monitoring program, and highlights the commitment of the agrochemical industry to supporting resistance management programs in developing countries.

The pod borer can drastically reduce pigeonpea yields.

Monitoring makes it possible to build up a detailed picture of seasonal changes in insecticide resistance to the insecticides commonly used by farmers to control *Helicoverpa*. The seasonal changes in *Helicoverpa* resistance to a pyrethroid insecticide (cypermethrin) at ICRISAT Center show that resistance increases from September through March. This is because of the cumulative effect of insecticide applications to field crops in the district which exert intense selection pressure on *Helicoverpa* populations. By March 1992 almost 90% of the *Helicoverpa* collected from fields at ICRISAT Center were highly resistant to cypermethrin. This was confirmed by the findings of ICRISAT agronomists

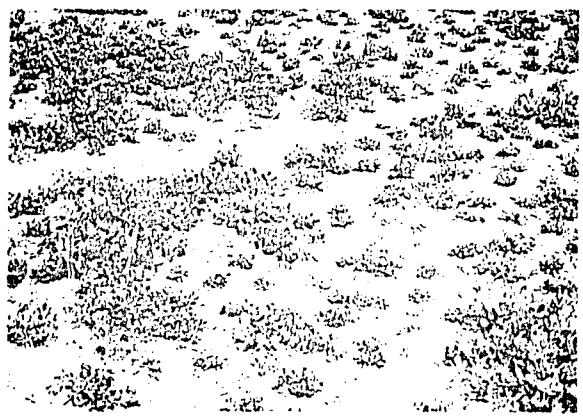
and cereals entomologists working together on the effect of cropping systems and insecticides on the abundance of *Helicoverpa* and its natural enemies. They found that there were more pests on sprayed plots than on nonsprayed plots at ICRISAT Center, clearly indicating the deleterious effects of insecticides on natural enemy populations. Studies are in progress to define the role of natural enemies in pod borer management. These, and results from the other monitoring locations will help in the development of badly needed insecticide resistance management strategies.

One of the ways to combat insecticide resistance is to cut down the number of times a crop is sprayed. To do this it is necessary to find out just when to apply the insecticide. Using a pigeonpea simulation model developed at NRI it was found that a single spray applied 10 days after 50% flowering gave significant *Helicoverpa* control for the following 2 weeks, whereas sprays applied a week earlier or a week later were ineffective. This experiment is the first step in providing guidelines to farmers on the most efficient use of insecticides to control pod borers on pigeonpea.

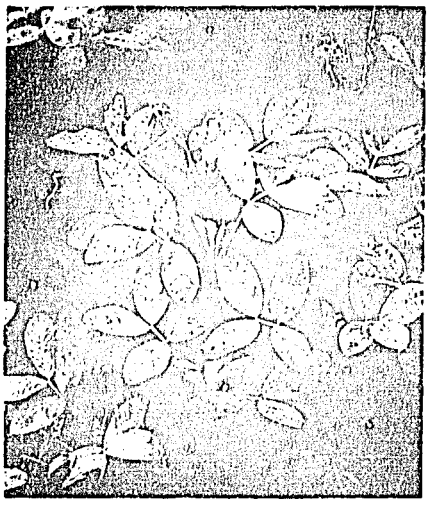
Combating the Virus Threat

Recent rapid advances in biotechnology have made it possible to develop highly sensitive, reliable, and rapid diagnostic assays for virus detection. The Virology Unit at ICRISAT Center has worked on the adaptation of these techniques to detect specific viruses affecting ICRISAT's mandate crops. Today the most widely used test for the detection of viruses is known as ELISA (a shortened form of 'enzyme-linked immunosorbent assay'). A particularly simple form of ELISA has been modified for use in developing countries to detect most of the important viruses of ICRISAT mandate crops in a cost-effective manner.

Polyclonal antibodies to viruses have been produced in rabbits and are effectively used for routine virus detection. Monoclonal antibodies (known as McAbs) can provide more consistent means for virus detection than polyclonal antibodies. McAb production is relatively expensive, but McAbs can be produced in large quantities and stored at low temperatures for indefinite periods of time. With assistance from the Asian Development Bank McAbs have been produced at ICRISAT Center for three important groundnut viruses, and used to precisely characterize peanut bud necrosis virus.



Groundnut plants affected by the peanut clump virus that is transmitted by a soilborne fungus.



Peanut stripe virus symptoms.

Unfortunately, some viruses cannot be reliably detected by ELISA techniques. These include peanut clump virus, a fungus-transmitted virus occurring in India and in Africa, and certain types of the groundnut rosette virus that causes major yield losses in Africa. In such cases a technique known as 'nucleic acid hybridization' has proved to be effective. In collaboration with virologists at the Scottish Crop Research Institute (SCRI) funded by the Overseas Development Administration Plant Sciences Programme, UK, a library has been prepared of cDNA clones covering the entire genomic range of the Hyderabad isolate of Indian peanut clump virus. These are currently being used at ICRISAT Center to detect all the isolates of peanut clump virus.

Rapid advances in biotechnology make it possible to use genetic engineering techniques to introduce resistance to virus diseases into crop cultivars. These techniques are invaluable when genes conferring resistance to viruses cannot be incorporated by conventional breeding methods. Significant progress has been made along these lines in the generation of a groundnut cultivar able to resist both peanut clump and peanut stripe viruses. This progress has been achieved in collaboration with SCRI, the Noble Foundation in Oklahoma, USA, and a number of other mentor institutions.

Reducing the Toxin Risk in Asia and Africa

In many western African countries aflatoxin contamination of groundnut is of major significance to both public health and export trade potential. Groundnuts can be infected by *Aspergillus flavus* the fungus responsible for producing aflatoxin when it invades kernels, either before or after harvest. Pre-harvest infection is a more serious threat when groundnuts suffer end-of-season drought stress and are more susceptible to fungal invasion. One way to reduce aflatoxin contamination is by the use of cultivars resistant to both invasion by *A. flavus*, and aflatoxin contamination once they are invaded.

Sources of resistance have been reported from India, Senegal, and USA. Six varieties bred at ICRISAT Center have consistently shown improved levels of resistance to seed invasion by the fungus, and high pod yield. These varieties have yielded on average 9 to 23% more pods than the resistant control cultivar in various evaluations across seasons and locations in India. One variety, ICGV 88145 is outstanding; it has

consistently shown high levels of resistance over three seasons, and on average produced 18% more pod yield than the resistant control in ten evaluations.

The search for resistance is also being persued in western Africa by ICRISAT scientists working at the ICRISAT Sahelian Center. Between 1989 and 1991, in collaboration with national research institutions in Burkina Faso, Niger, and Senegal they tested 25 lines assembled from a range of resistant lines, breeding lines from ICRISAT Center, and cultivars from western Africa. Trials were conducted in all three countries to check the stability of resistant lines in western Africa; to test western African cultivars for their reaction to the pathogen, and aflatoxin, and to test advanced breeding lines for their levels of resistance.

Average seed contamination varied with year and location from 5% to 37%. Among the ICRISAT advanced breeding lines that have resistant parents, three were resistant, showing that they had inherited the genes for resistance. Fungal contamination was generally well correlated with aflatoxin content, which ranged from 1 to 450 parts per billion. Only one line was highly infected with *A. flavus*, but contained only a low level of aflatoxin, suggesting that this line is resistant to aflatoxin production in western African conditions.

Although there were differences in the levels of both fungal infection and alflatoxin contamination between the five trial locations, there was no correlation between locations and genotypes. This suggests that screening for resistance can be effective at a single location, i.e., the one where infection is most severe. The trials showed that the ICRISAT Sahelian Center is an appropriate place to conduct future trials.

Spreading the Word

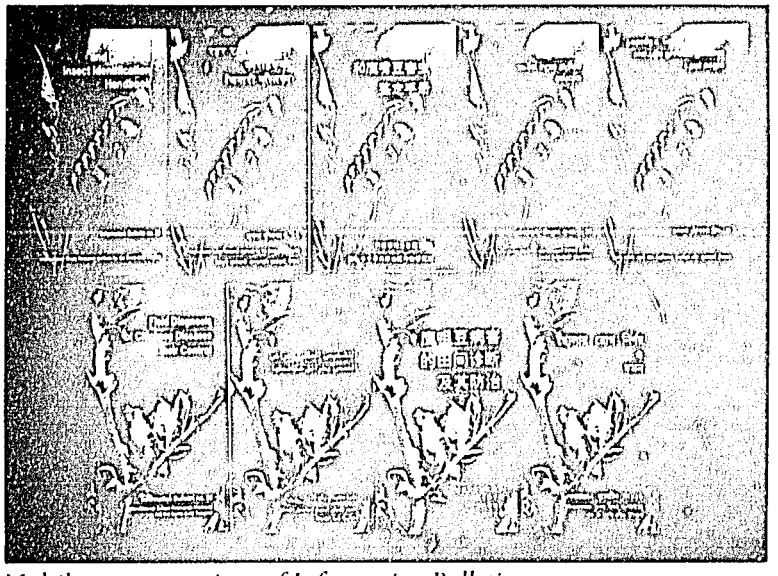
During the year 78 713 copies of ICRISAT publications and 61 150 copies of our four newsletters were distributed worldwide. This is twice the number distributed in 1991 and includes 6444 copies distributed through the Cereals and Legumes Asia Network (CLAN) to collaborators in 11 member countries in Asia. A special follow-up by the Human Resource Development Program (HRDP) renewed contact with 356 previous participants in HRDP activities, and as a result 4139 copies of publications were sent to 55 countries. A new **Skill Development Series** from HRDP includes nine printed issues and seven computer-aided lessons. These first 13 issues, which were widely distributed to HRDP participants, had a very positive reception.

The year saw a welcome increase in the number of copublished new titles; two with other CGIAR centers, one with CAB International, and one with a national program.

ICRISAT publications, in particular those used by field-based scientists and extension staff, need to be translated into local languages. The Cereals and Legumes Asia Network (CLAN) has initiated this process; two Information Bulletins were translated by and copublished with the national programs of four countries (Bangladesh, China, Myanmar, Nepal, and Sri Lanka); and with the International Center for Research in the Dry Areas (ICARDA). CLAN will work towards further translations of existing and forthcoming titles.

In addition to the material published or copublished by ICRISAT, 52 articles by ICRISAT staff were published in international scientific journals, and 29 papers presented by ICRISAT scientists at workshops or conferences were published in proceedings.

ICRISAT videos **Participatory Research with Women Farmers**, and **Living with Drought** have proved to be very popular. The videos were distributed by the Television Trust for the Environment (TVE), UK. TVE is an independent international charity co-sponsored by the United Nations Environment Programme, Central Independent Television plc, and the World Wide Fund for Nature. It is working to raise awareness of environment, development and health issues through the media. A total of 704 copies of **Participatory Research with Women Farmers** (English 468, Spanish 42, and French 43) were distributed in 68 countries, and 112 copies of **Living with Drought** (English 35, and French 77) were distributed in 47 countries. A recent video production, **Peas for Prosperity** was distributed to 14 countries (60 copies) during 1992.

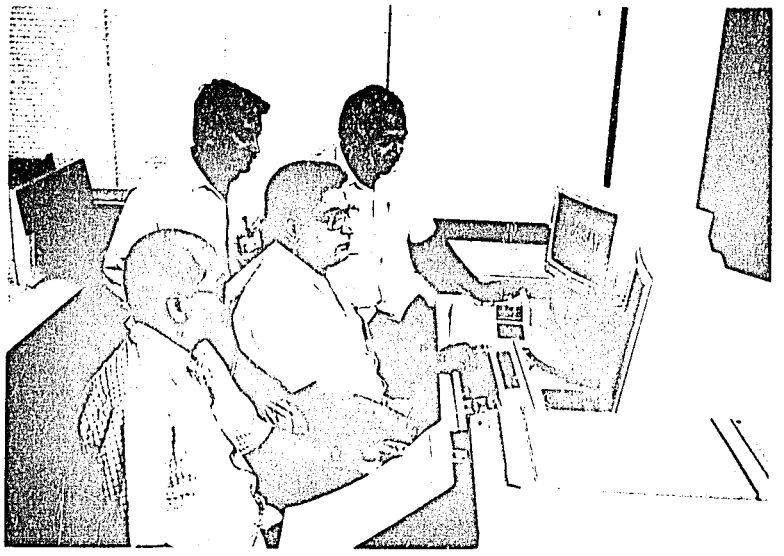


Multilanguage versions of Information Bulletins translated by, and copublished with several national programs through CLAN.

An updated version of **ICRISAT in Print** that includes details of all publications by ICRISAT and its staff over the past 20 years will soon be available on searchable diskettes.

New publications during 1992 are listed on pages 70 and 71.

Sharing Information



Composing an ICRISAT publication.

In 1992 over 5600 records were added to the Semi-Arid Tropical Crops Information Service (SATCRIS) database which now holds 36 000 records. The Dissertations Abstracts International and the SESAME databases were added to the collection of databases on CD-ROM, further improving ICRISAT's capability to respond to search requests. The Selective Dissemination of Information (SDI) service added 49 new users from 7 countries in Asia and Africa. It now reaches 388 users in 47 countries. The on-demand search service registered a 40% increase in demand over 1991. Users from 19 countries in Asia and Africa were provided with the results of 701 searches in 1992.

A database on the groundnut aflatoxin problem was developed and is available on diskette. A User's Manual was produced to accompany the diskette, and the package is being distributed worldwide on request. Work has started on the development of a computer-based advisory system on groundnut plant protection.

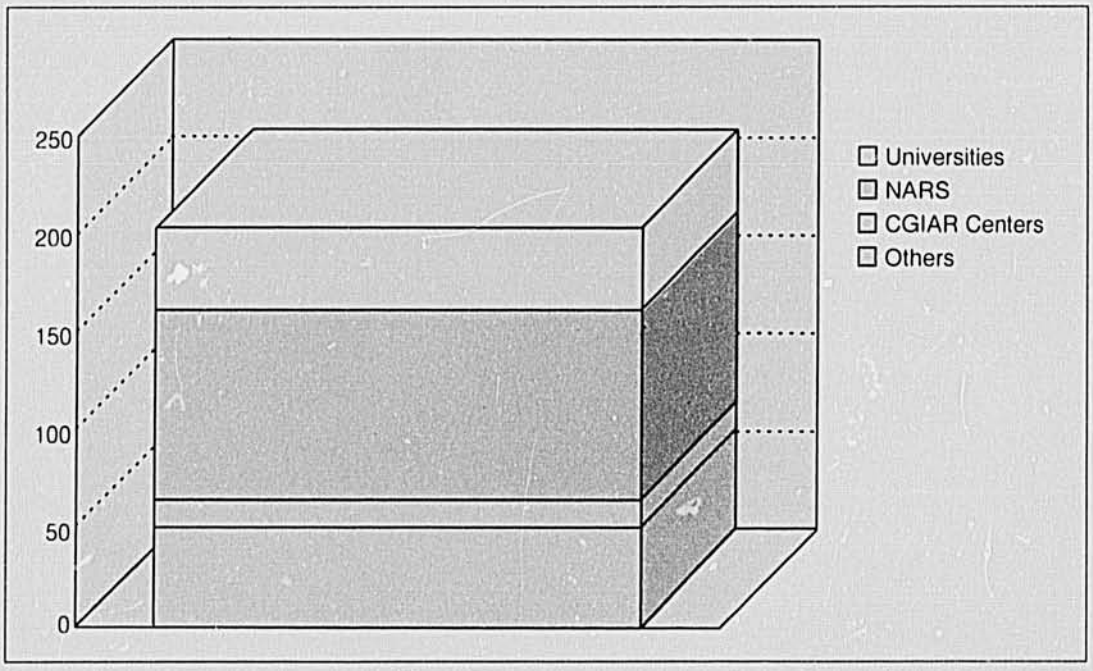
Several developments in francophone western Africa have contributed to improved coordination of acquisitions, better document delivery and exchange of publications, and more focused targeting of SATCRIS services to national programs. The French Centre d'information pour le développment économique et social (CIDES) sponsored the production of a bibliography on research in Niger in collaboration with the ICRISAT Sahelian Center library. It will be published by CIDES in 1993. National programs in Ethiopia, Mozambique, Nigeria, Uganda, and the Arab world were provided with software developed by the library and/or a database on the Union Catalog of Serials in the International Agricultural Research Centers. Formal working relationships were established between the ICRISAT Sahelian Center and Niger's national program and the Institut national de recherches agronomiques du Niger (INRAN), Centre régional de formation et d'application en agrométéorologie et hydrologie opérationnelle (AGRHYMET), and RESADOC.

ICRISAT Networks and Collaborators

Networks associated with ICRISAT programs

	Asia	Latin America		Western Africa		Eastern Africa	Southern Africa
Network	CLAN	CLAIS (Central America and Caribbean)	CLAIS (South America)	WCAMRN ROCAFREMI	WCASRN ROCARS	EARSAM	SMIP
Crop(s)	All mandate	Sorghum	Sorghum	Millet	Sorghum	Sorghum, Millets	Sorghum, Millets
Member countries	Bangladesh, China, India, Indonesia, Myanmar, Nepal, Pakistan, Philippines, Sri Lanka, Thailand, Vietnam	Costa Rica, Dominican Republic, El Salvador, Haiti, Guatemala, Honduras, Mexico, Nicaragua, Panama	Argentina, Bolivia, Brazil, Colombia, Ecuador, Mexico, Peru, Trinidad and Tobago, Venezuela	Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, Gambia, Ghana, Guinea Bissau, Mali, Mauritania, Niger, Nigeria, Senegal, Togo	Benin, Burkina Faso, Cameroon, Central African Republic, Chad, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea Bissau, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo	Burundi, Ethiopia, Kenya, Rwanda, Somalia, Sudan, Tanzania, Uganda	Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, Swaziland, Tanzania, Zambia, Zimbabwe
Associated institutions	Regional and international in Asia	INTSORMIL, IICA, CIAT, CATIE, CIMMYT	INTSORMIL, IICA, CIAT, CATIE, CIMMYT	SAFGRAD, INSAH	SAFGRAD, INSAH	INTSORMIL, SAFGRAD, ICIPE	SACCAR
Coordination	ICRISAT Center	LASIP	LASIP	ISC, Niger	WASIP, Mali	EARCAL	SMIP
Support	ADB, UNDP	IICA, PCCMCA, INTSORMIL, Seed Companies	IICA, PCCMCA, INTSORMIL, Seed Companies	Swiss Development Cooperation	USAID	USAID	CIDA, GTZ, USAID

Institutions working in collaboration with ICRISAT on research projects in 1992.



Left: *The harsh semi-arid environment of Rajasthan*

Technology Exchange 1992

ICRISAT lays great emphasis on sharing its knowledge. In addition to the Human Resource Development Programs that involve many participants at most ICRISAT locations, staff share the results of their work through workshops, field days, training courses on specialized topics, and in meetings and tours. The following is a representative selection of those held in 1992.

January

Monitoring Tour and Workshop on 'Managing chickpea, pigeonpea, and groundnut in rice-based cropping systems', held in Myanmar, 42 participants from 11 Asian countries.

Research Farm Management Training Course, held at ICRISAT Center, 9 participants from 7 countries.

WARDA/ICRISAT Training Course on 'Computer application and statistical analysis in agricultural research', held at ISC, 16 participants from 7 countries.

February

Groundnut Production Training Course, held at ICRISAT Center at AOAD request, 16 participants from 4 countries.

March

Fifth Regional Groundnut Workshop for Southern Africa, held in Malawi, 35 participants.

Regional Workshops for Review and Planning of Pigeonpea Research in Eastern and Southern Africa, held in Kenya (27 participants) and Malawi (14 participants).

Workshop to 'Coordinate research on groundnut transformation and regeneration', held at Wageningen, Netherlands, 14 participants.

WCAMRN Workshop on Pearl Millet Improvement, held at ISC, 13 participants from 14 countries.

Ninth Annual CLAIS/PCCMCA Meeting, held in Managua, Nicaragua.

First SADC Regional Groundnut Plant Pathology Training Course held in Malawi, 23 participants from 7 SADC countries.

FAO/ICAR/ICRISAT Regional Training Course on 'Quality aspects of food legumes and coarse grains with special emphasis on nutritional and antinutritional factors', held at ICRISAT Center, 22 participants from 11 countries.

ICAR/ICRISAT Peanut Stripe Virus Training Course, held at ICRISAT Center, 9 participants from India.

Field Day for Indian Seed Producers held at ICRISAT Center, 55 participants including 26 private, 4 public seed production agencies, and All India Project Coordinators.

April

Vietnam/AGLN/AGLOR Review and Planning Meeting, held in Vietnam.

May

NBPGR/ICRISAT GRU Annual Planning Meeting for Germplasm Evaluation and Exploration, held in New Delhi, India.

AIDAB/COMCIAN Regional Crop Modeling Workshop at ICRISAT Center, 20 participants from 6 Asian countries.

June

AGLOR Review and Planning Meeting, held in Rampur, Nepal, 16 participants.

KARI/EARCAL Field Day, held at Kiboko Research Station, Kenya, 98 participants.

July

Training Course on 'Strengthening national research in plant genetic resources', held at the Central Agricultural Research Institute, Yezin Myanmar.

August

CLAIS International Sorghum Short Course, held in Brazil.

IITA/INRAN/University of Arkansas/ICRISAT Experiment Station Operations Management Course, held at ISC, 28 participants from 7 countries.

Pigeonpea Monitoring Tour in eastern and southern Africa.

ILCA/ICRAF/IFDC/ICRISAT Computer and Statistical Training Course, held at ISC.

September

Regional Sorghum Scientists' Meeting, held in Kano, Nigeria.

WASIP Nigeria Field Days, held in Bagauda, Nigeria.

Sorghum and Pearl Millet Research Planning Meeting for the SADC Region, held at SADC/ICRISAT SMIP, 53 participants from SADC countries.

Third Regional Groundnut Workshop for West Africa, held in Ouagadougou, Burkina Faso, 50 participants from 14 countries.

CIAT/ICRISAT Training Workshop on 'Food quality and consumer testing', held at SADC/ICRISAT SMIP, 8 participants.

October

First Annual CLAIS South America Meeting, held in Brazil.

IRRI/ICRISAT Meeting on Ecoregional Approach in Asia, held at IRRI, Philippines.

International Bacterial Wilt Symposium, held at Kaohsiung, Taiwan 91 participants from 25 countries.

EARSAM 8th Regional Workshop, held in Wad Medani, Sudan, 43 participants from 7 countries.

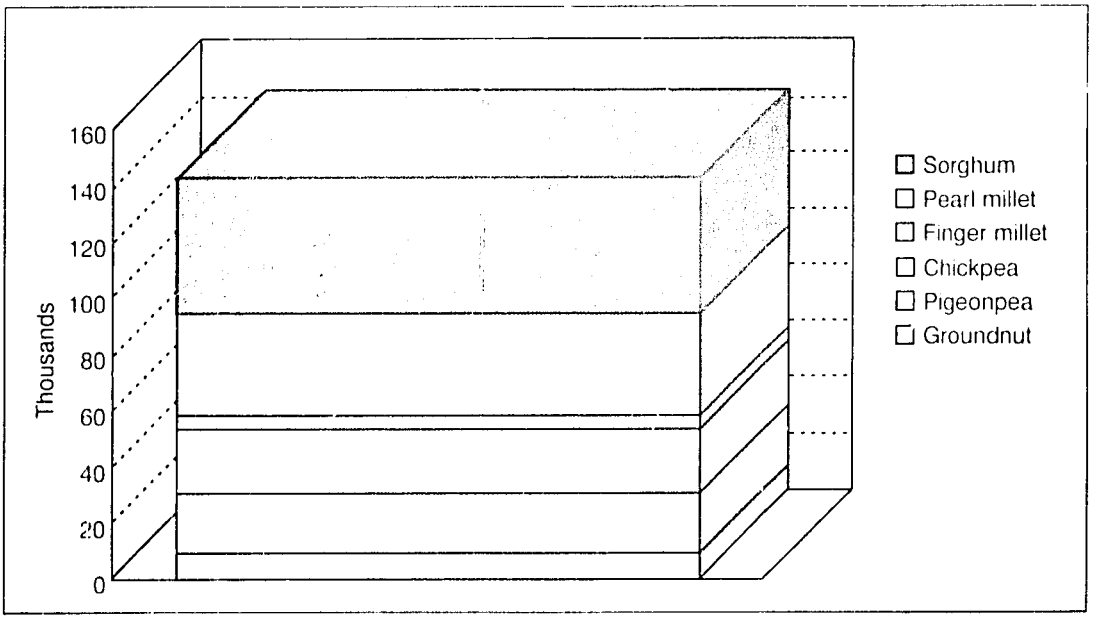
International Symposium on 'Assessment, monitoring and management of stressed agricultural ecosystems', held in New Delhi, India.

November

ICARDA/ICRISAT Workshop on Adaptation of Chickpea, held at ICARDA, Syria.

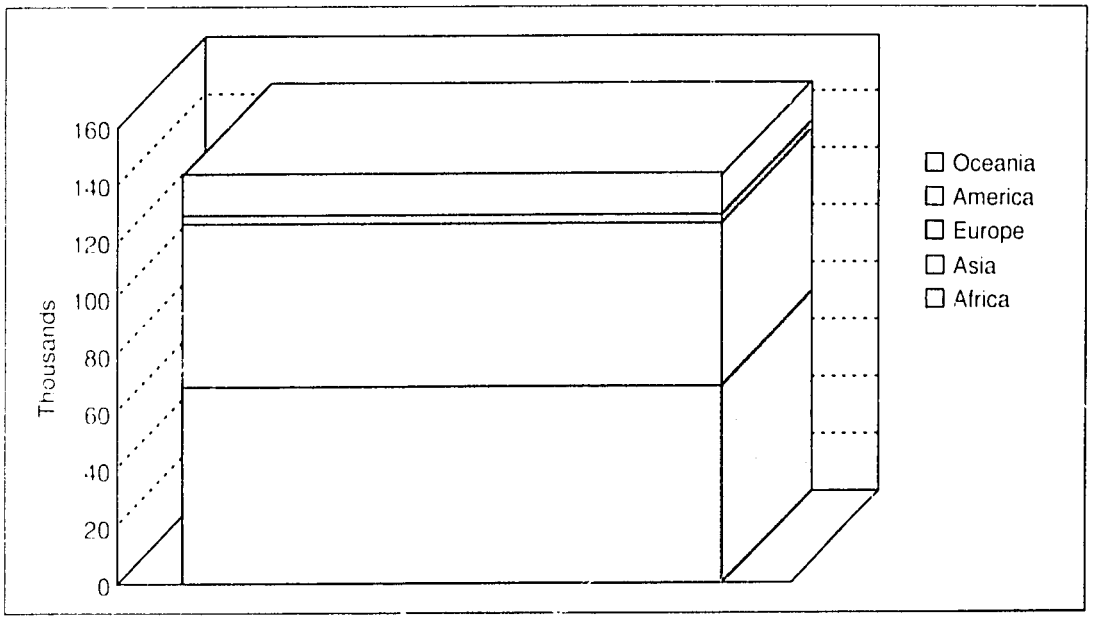
Second Groundnut Bacterial Wilt Working Group Meeting, held in Taiwan, 21 participants.

Seed Distribution 1992



Numbers of seed samples of each ICRISAT mandate crop including germplasm, breeding material and trials and nursery entries distributed from all ICRISAT locations in 1992.

Numbers of seed samples of all ICRISAT's mandate crops including germplasm, breeding material and trials and nursery entries distributed worldwide from all ICRISAT locations in 1992.



ICRISAT Plant Material 1992

ICRISAT name	Release name	Country of release	Remarks
ICRISAT material directly released as cultivars by national programs			
Pearl Millet			
SDMV 89004	PMV 2	Zimbabwe	First pearl millet jointly produced by SADC/ICRISAT SMIP and Department of Research and Specialist Services, Zimbabwe. Early-maturing, escapes drought. Good farmer acceptance. Positively received in Malawi, and in on-farm trials in Namibia and Botswana.
Finger Millet			
SDFM 723	FMV 2	Zimbabwe	One of the first two finger millets released in Zimbabwe. Derived from PI 462073 that originated in India. Selected through joint collaborative trials by the Crop Breeding Institute, Department of Research and Specialist Services, and SADC/ICRISAT SMIP.
Chickpea			
ICCV 10	Bharati	Central and Southern Zones of India	Short- to medium-duration, resistant to wilt, less susceptible to dry root rot and *Helicoverpa* than controls.
FLIP 83-48C	Rizki	Morocco, Pakistan, and Turkey	Kabuli cultivars developed by the ICARDA/ICRISAT Chickpea Project. All resistant to ascochyta blight and cold-tolerant. Released for winter sowing in traditionally spring-growing areas.
FLIP 84-92C	Douyet		
FLIP 82-259C	Adrin 92	Morocco	
FLIP 85-14C	Menemen 92	Turkey	
FLIP 85-60C	Izmir 92	Turkey	
		Turkey	
FLIP 81-293C	Noor 91	Pakistan	Kabuli cultivar developed by the ICARDA/ICRISAT Chickpea Project, resistant to ascochyta blight and cold-tolerant. Released for winter sowing to replace an ascochyta blight susceptible cultivar Pb1 released in 1933!
ICPX 78120-WB-WB-WB	Birsa-Arhar-1	India	First variety released from an ICRISAT segregating population resistant to wilt disease.
Pigeonpea			
ICP 11384	Bageswari	Nepal	Medium-duration selections identified from germplasm supplied by ICRISAT, resistant to sterility mosaic disease.
ICP 6997	Rampur rhar	Nepal	
ICPL 85010		Himachal Pradesh, India	Identified for prerelease, does well in hilly areas.
ICPL 85012		Maharashtra, India.	Identified for prerelease in Vidarbha
ICRISAT material under advanced evaluation/consideration for release			
Sorghum			
2KX 17	Tegemeo	9 countries	ICRISAT-bred, widely grown in Tanzania, in WASIP/NARS trials for sooty stripe resistance.
ICSH 507		Côte d'Ivoire	In on-station trials
Malisor 84-1		Senegal	In prerelease evaluation
ICSV 401 IN		Ghana	In prerelease evaluation
ICSV 111 IN			
ICSV 16-5-B5			
Chickpea			
ICCL 86237		Bangladesh	Tolerant of botrytis gray mold
ICCX 4058 (Dhanush × K850)		Nepal	The cross produced high-yielding, large-seeded, botrytis-resistant lines; two are under consideration for release
ICCL 83228		Bangladesh	High-yielding, wilt-resistant, likely to be released
ICCL 83105		Bangladesh	High-yielding, wilt-resistant, large-seeded, likely to be released

CRISAT name	Release name	Country of release	Remarks
ICRISAT material under advanced evaluation/consideration for release *(continued.)*			
Groundnut			
ICGV 87157		Sierra Leone	Resistant to rust and tolerant of late leaf spot, in on-farm trials.
ICGV 88372 ICGV 88412		Cyprus	Large seed mass, suitable for confectionery use, in final evaluation.
ICGV 86014 ICGV 86143		Tamil Nadu, India	Early-maturing, in adaptive trials at 40 locations.
ICGV 88398 ICGV 88438		India	Large-seeded, suitable for confectionery use. Identified for testing in AICORPO Hand Picked Selection Varietal Trial
ICGV 87354 ICGV 87359		India	Drought-tolerant, identified for large on-farm trials in drought-prone areas, AICORPO, India.
ICGV 86325 ICGV 86300		India	Final stage testing in AICRPO Zone V, India.
ICRISAT material used to develop new cultivars by national programs			
Sorghum			
ICA Yanuba HE 241		Colombia	Released by ICA, based on material provided by ICRISAT, selected for tropical areas of the Andean valleys.
ICSV 1079 BF ICSV 1078 BF		Western Africa	In use as *Striga*-resistant parents in four WCASRN trials.
Pigeonpea			
AKG 46	Akola	Maharashtra State, India	Short- to medium-duration, developed by scientists of Punjabrao Krishi Vidyapeeth, Akola, from ICRISAT-supplied material.
ICPL 85047		India	Identified as resistance source of wilt and sterility mosaic by AICPIP.
ICCL 86102 ICCC 86103		India	Recommended by AICPIP as donor parents for *Helicoverpa* resistance.
Elite germplasm/parental material released by ICRISAT			
Pigeonpea			
ICPL 87119		Central and Southern Zones, India	First medium-duration cultivar to be released since 1978 and first with multiple disease resistance (wilt and sterility mosaic) to be released at national level. Identified by AICPIP as resistance source.
Chickpea			
ICCV 2		Myanmar	Extra short-duration kabuli under consideration for release.
ICCC 42		India	Recommended by AICPIP as parental source of wilt and root rot resistance.
Groundnut			
ICGV 86031		India	High-yielding breeding line with multiple resistance to and/or tolerance of *Spodoptera*, leaf miner, jassid, thrips, bud necrosis virus, and iron chlorosis.
ICGV 86564		India	High-yielding, large-seeded breeding line with high oil content and improved oil quality.

Awards and Distinctions

Dr YL Nene receiving the Shri Om Prakash Bhasin Award.

Yeshwant L Nene, Deputy Director General, was honored with the 'Shri Om Prakash Bhasin Award for Science and Technology 1991', for his outstanding contributions to agriculture by the Prime Minister of India, His Excellency, PV Narasimha Rao. This award is presented annually to encourage scientists and technologists working in India.

C Fred Bentley, former Chairman of the ICRISAT Governing Board, became an External Fellow of the National Academy of Agricultural Sciences, India. He was also one of the three recipients of the 'International Recognition Award' of the Agricultural Institute of Canada. He attributes both these awards to his associatio with ICRISAT.

Leland R House, formerly Executive Director, Southern African Programs, was appointed a Fellow of the American Association for the Advancement of Science.

YL Nene, **SM Virmani**, Principal Scientist (Agroclimatology), Resource Management Program, ICRISAT Center, **K Anand Kumar**, Principal Scientist (Breeding) and Team Leader, Cereals, and **MVK Sivakumar**, Principal Scientist (Agroclimatology) and Team Leader, Resource Management Program, ICRISAT Sahelian Center, became Fellows of the Indian National Academy of Agricultural Sciences.

MVK Sivakumar, was nominated by the Government of Niger as a member of the Niger National Committee for the International Geosphere-Biosphere Program.

MP Haware, Senior Scientist (Pathology), Legumes Program, received the Dr MS Pavgi Award 1992 from the Indian Phytopathological Society.

AM Ghanekar, Plant Quarantine Officer, was elected a Fellow of the Indian Phytopathological Society.

RC Sachan, Senior Engineer, was elected Director (Technical Council), Soil Water Engineering, 1992-94 by the Indian Society of Agricultural Engineers.

MV Reddy, Senior Scientist (Pathology), was awarded the Jennaredy Venkat Reddy Prize by Andhra Pradesh Agricultural University (APAU). Instituted by the Farmers' Welfare Trust, Hyderabad, the prize honors eminent agricultural scientists working in the Telangana Region of Andhra Pradesh.

Soil Water Inorganic Nitrogen in Two Intercrop Components, Sorghum and Pigeonpea–A Pot Experiment a poster submitted by **O Ito**, **S Tobita**, **R Matsunaga**, **TP Rao**, and **C Johansen**, won the Best Poster Award at the International Symposium on Nutrient Management for Sustained Productivity.

Participatory Research with Women Farmers, a video conceived by former ICRISAT Principal Entomologist **M Pimbert** and directed by **PV Sateesh** of Development Perspectives, Hyderabad, won the Best Video Award in the 'Service category at a video festival organized by the Andhra Pradesh Chapter of the Public Relations Society of India.

RISAT/Natural Resources Institute (NRI), UK. Memorandum of Understanding signed 7 January, for general collaboration and information exchange in integrated pest anagement.

yanmar-Cereals and Legumes Asia Network (CLAN)/ICRISAT Work Plan 1992/93. irst Letter of Agreement under CLAN, developed at a review and planning meeting eld 27-29 January in Myanmar, attended by representatives of all 11 CLAN ountries.

CRISAT/Chinese Academy of Agricultural Sciences (CAAS) Collaborative Work Plan 992-94. Signed at ICRISAT Center 2 March, supplements the Agreement of Cooperation signed in Beijing on 2 May 1988. Covers a wide range of activities of otential interest to both parties.

CRISAT/Government of Kenya. Agreement signed 2 April, for the establishment of a egional center for ICRISAT in Kenya. The center will assist Kenya and other ountries of eastern Africa to enhance food security through sustainable agriculture in he semi-arid tropics of the region.

Sri Lanka-AGLN/ICRISAT Work Plan 1991/92. Signed 29 April, for collaboration in agricultural research for the development of ICRISAT's cereals and legumes and their farming systems.

ICRISAT/International Center for Agricultural Research in the Dry Areas (ICARDA). Memorandum of Understanding signed 27 May, for reciprocal duplication of chickpea germplasm collections and data.

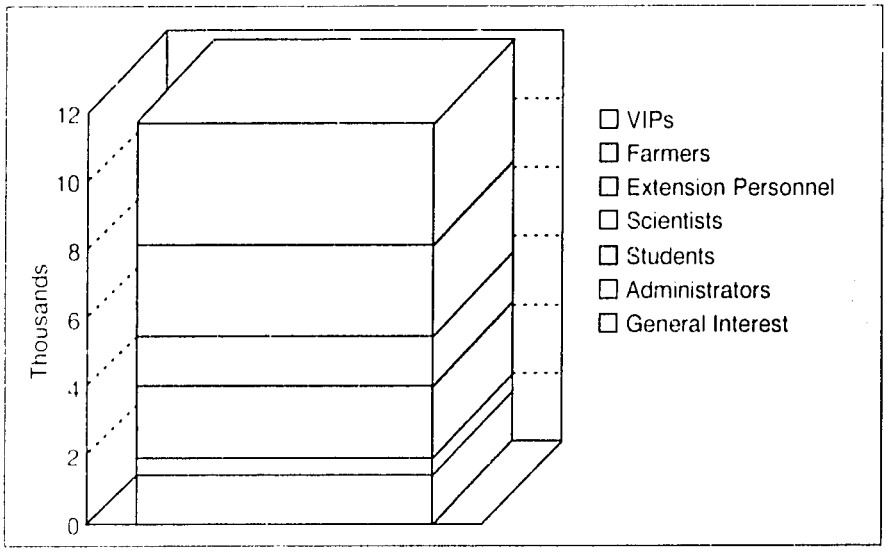
ICRISAT/Indian Council of Agricultural Research (ICAR). Agreement signed 15 June, for a collaborative project on 'Farmers' preferences and production constraints for pearl millet genotypes in rainfed crop-livestock systems in different agroecological environments of Rajasthan.'Involves the Central Arid Zone Research Institute (CAZRI), Rajasthan Agricultural University, Government of Rajasthan, and ICRISAT.

ICRISAT/International Livestock Centre for Africa (ILCA). Three-year extension to the existing Memorandum of Understanding, signed 3 August.

Collecting chickpea in Pakistan.

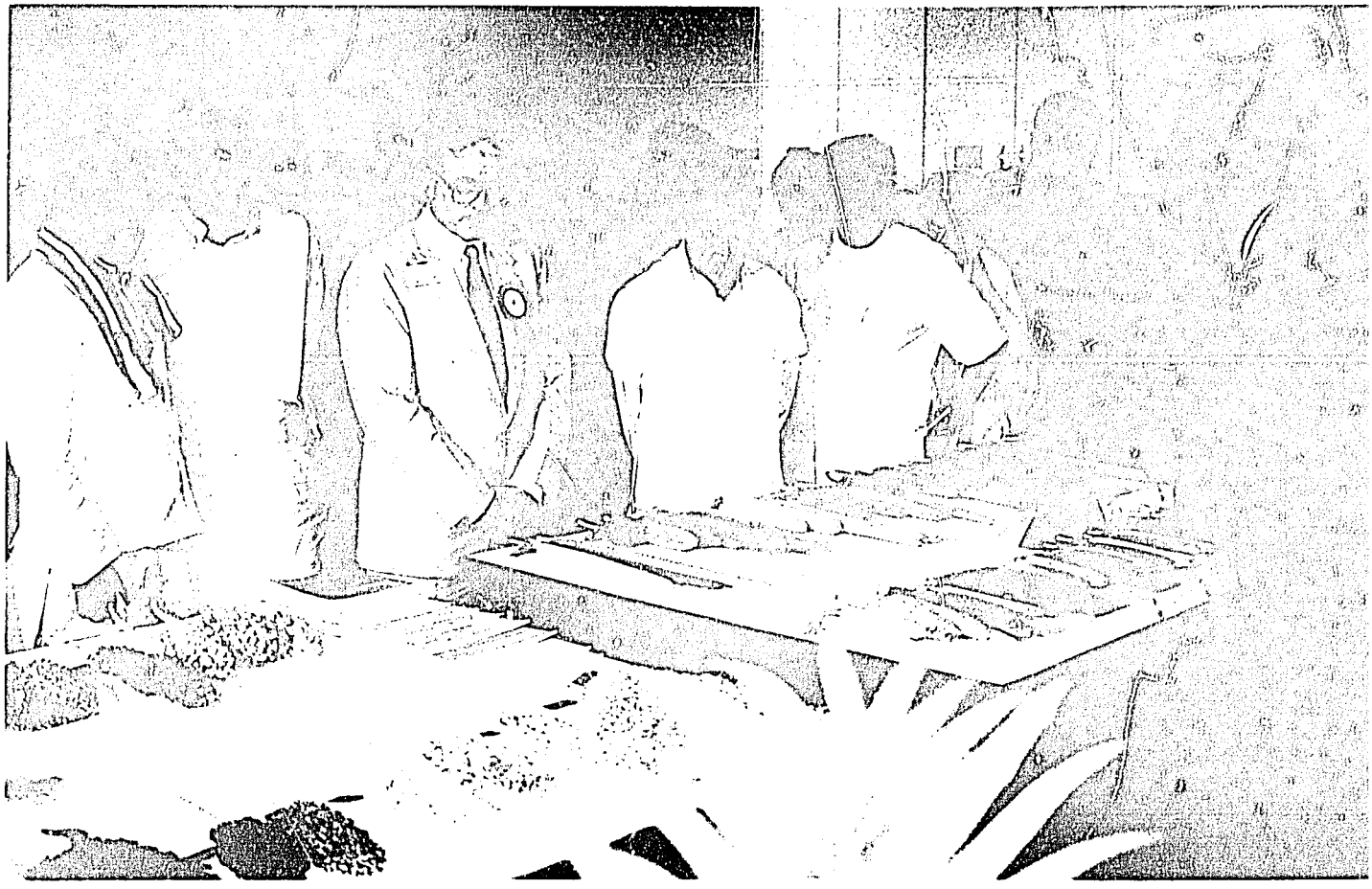
ICRISAT/International Board for Plant Genetic Resources (IBPGR). Memorandum of Understanding on collaboration with the ICRISAT Sahelian Center signed 25 September, to develop activities on the conservation and use of plant genetic resources of mandate crops of ICRISAT and other crops of national and regional interest.

Visitors to ICRISAT 1992



Total numbers of visitors to all ICRISAT locations in 1992.

His Excellency P V Narasimha Rao, Prin Minister of India (center) inspecting tl range of diversity shown by pearl mill accessions in the ICRISAT Gene Ban during his visit to ICRISAT Center–tl highlight of the celebrations for tl Institute's 20th Anniversar



ICRISAT in Print 1992

Books

Utilization of sorghum and millets. M.I. Gomez, L.R. House, L.W. Rooney, and D.A.V. Dendy (eds.). ISBN 92-9066-160-7.

A compilation of 28 papers presented at a workshop in Bulawayo, Zimbabwe, in Feb 1988, plus working group discussions on the policy, practice, and potential relating to the uses of sorghum and millets throughout the world. The book suggests directions for research and development efforts aimed at better utilization of sorghum and millets.

Sorghum and millets diseases: a second world review. W.A.J. de Milliano, R.A. Frederiksen, and G.D. Bengston, (eds.). ISBN 92-9066-201-8.

Reviews progress made on sorghum diseases since the first global workshop held in India in 1978, identifies research needs and goals for the next decade, and discusses the strengthening of working relationships among pathologists studying sorghum and millets diseases.

Biotechnology and crop improvement in Asia. J.P. Moss (ed.) ISBN 92-9066-198-4.

The result of a workshop held at ICRISAT Center 3-7 Dec 1990. Outlines the role of the Asian Development Bank (ADB) in strengthening biotechnology research in Asia and those crops and areas of crop improvement to which biotechnology could be applied. Presents the Indian biotechnology program, and highlights the advantages and disadvantages of private companies involvement in biotechnology research. Reviews the major disciplines in biotechnology, and contains a glossary and index.

Database on the groundnut aflatoxin problem and users' manual. V.K. Mehan, L.J. Haravu, D. McDonald, S. Jayanthi, and P.K. Sinha. ISBN 92-9066-215-8.

Supplied as 10 diskettes containing annotated bibliographic data on all aspects of the groundnut aflatoxin problem. The database is usable with the Mini-Micro CDS/ISIS Database Management Software Package developed by UNESCO. A Users' Manual provides instructions on installation, interpretation, and use.

Descriptores para mani, Descriptors for groundnut, Descripteurs pour l'arachide. ISBN 92-9043-139-3. Copublished with the International Board for Plant Genetic Resources (IBPGR).

This trilingual volume in the internationally accepted format for IBPGR descriptor lists updates two earlier versions. The use of its universally understood 'language' for plant genetic resources data will assist the utilization of germplasm throughout the international plant genetic resources network.

Research Bulletins

An occasional series in which ICRISAT staff and consultants report the findings of long-term research projects. The target audience is peer scientists worldwide.

No.16. **Identification and utilization of smut resistance in pearl millet.** R.P. Thakur, S.B. King, K.N. Rai, and V.P. Rao. ISBN 92-9066-217-4. **Identification et utilisation de la résistance au charbon du mil.** ISBN 92-9066-236-0.

Describes the progress made from 1976 to 1990 at ICRISAT Center, on the identification and utilization of smut resistance in pearl millet. Aims to help breeders and pathologists involved in the genetic improvement of pearl millet, to achieve sustained increase in productivity by reducing grain yield losses from smut.

Information Bulletins

This occasional series of short, well-illustrated publications is the main vehicle for information derived from ICRISAT research findings that has immediate application. The target audiences are national agricultural program scientists, and extension staff in countries of the semi-arid tropics.

No. 32. **Techniques to screen sorghums for resistance to insect pests.** H.C. Sharma, S.L. Taneja, K. Leuschner, and K.F. Nwanze. ISBN 92-9066-213-1.

Sorghum is one of the most important cereal crops in the semi-arid tropics. Grain yields on peasant farms are generally low, insect pests being one of the major factors limiting production. This publication describes techniques used to screen for resistance, methods of evaluating insect damage, and the sources of resistance to the major pests.

No. 33. ***Busseola fusca* (Fuller), the African maize stalk borer: a handbook of information.** K.M. Harris, and K.F. Nwanze. ISBN 92-9066-224-7. Copublished with CAB International.

In two parts; the first comprises a comprehensive review of the biology and management of *Busseola fusca*, and the second an annotated bibliography of nearly 400 references published between 1900 and 1990.

No. 36. **Field diagnosis of groundnut diseases.** P. Subrahmanyam, S. Wongkaew, D.V.R. Reddy, J.W. Demski, D. McDonald, S.B. Sharma, and D.H. Smith. ISBN 92-9066-255-7.

Diseases are major constraints to groundnut production throughout the world. This handbook is designed to assist agricultural research and extension workers, who may have little formal training in plant pathology, to make tentative diagnoses of groundnut diseases caused by a wide range of pathogens. The most characteristic field symptoms of each disease are illustrated and described. A French edition is in preparation.

No. 26. **Pigeonpea and chickpea insect identification handbook.** W. Reed, S.S. Lateef, S. Sithanantham, and C.S. Pawar. **Nepali** (ISBN 92-9066-241-7), **Chinese** (ISBN 92-9066-243-3), **Singhala** (ISBN 92-9066-244-1), **Tamil** (ISBN 92-9066-245-X). **Myanma** (ISBN 92-9066-242-5) (in preparation). Translated by and copublished with the National Programs through Cereals and Legumes Asia Network (CLAN).

No. 28. **Field diagnosis of chickpea diseases and their control.** Y.L. Nene, M.V. Reddy, M.P. Haware, A.M. Ghanekar, and K.S. Amin. **Nepali** (ISBN 92-9066-246-8), **Chinese** (ISBN 92-9066-248-4), **Bangla** (ISBN 92-9066-249-2), **Myanma** (ISBN 92-9066-247-6) (in preparation).

Translated and copublished with the National Programs, and **Arabic** (ISBN 92-9066-250-6) translated by and copublished with the International Center for Agricultural Research in Dry Areas (ICARDA), through the Cereals and Legumes Asia Network (CLAN).

Conference/Workshop Proceedings

The Institute's sponsorship of a conference or workshop, especially at the international level, normally includes publication of the proceedings or a summary report by ICRISAT.

Enhancing grain legumes research in Asia: summary proceedings of the Asian Grain Legumes Network Coordinators' Meeting, 10-12 December 1990. ICRISAT Center, India. D.G. Faris, and O.P. Rupela. (eds.). ISBN 92-9066-221-2

Reviews the activities of the Asian Grain Legumes Network (AGLN). Examines the progress made by AGLN in collaborative activities involving groundnut, chickpea, and pigeonpea since the last meeting in Dec 1988. Presents the past, present, and future role of networks in AGLN countries. Recommends ways to enhance collaborative research on AGLN crops and other network activities.

Sorghum: research and development network for Asia: report of the Consultative Meeting to Consider the Establishment of a Sorghum Research and Development Network for Asia, 16-19 Sep 1991, ICRISAT Center, India. G. Alagarswamy, J.W. Stenhouse, and C.M. Pattanayak. (eds.). ISBN 92-9066-222-0.

A report of a meeting of Asian national scientists and administrators to discuss sorghum production constraints in Asia, and the means to alleviate them. The group resolved to establish a Sorghum Research and Development Network for Asia, whose overall goal is to elevate the status of sorghum from that of a mere subsistence crop to a high-value crop.

Soil water balance in the Sudano-Sahelian Zone: summary proceedings of an International Workshop, 18-23 Feb 1991, Niamey, Niger. Bilan hydrique en zone soudano-sahélienne: comptes rendus d'un Atelier international, 18-23 février 1991, Niamey, Niger. M.V.K. Sivakumar, J.S. Wallace, and C. Renard, (eds.). ISBN 92-9066-210-7.

This workshop brought together scientists from many disciplines to share their experience and to contribute towards evolving an effective synthesis of the state of water balance research in the Sudano-Sahelian Zone. This bilingual volume presents summaries of the five sessions, reports of the planning groups that dealt with new systems and sites, measurement and analysis of weather, crop, and soil data, modeling, technology transfer, and management, the main issues for future research and collaboration, and 21 recommendations for action.

ICRISAT in Print 1992

Pigeonpea in eastern and southern Africa: summary proceedings of the Launching Meetings for the African Development Bank/ICRISAT Collaborative Pigeonpea Project for Eastern and Southern Africa, 17-18 Mar 1992, Nairobi, Kenya, and 30-31 Mar 1992, Lilongwe, Malawi. S.L. Silim, S. Tuwafe, and E.M. McGaw. (eds.) ISBN 92-9066-229-8.

Two meetings took place in March 1992 to launch an African Development Bank-funded collaborative pigeonpea project for eastern and southern Africa. Of particular importance are the recommendations and suggested work plans for initiating collaborative pigeonpea research in the two regions.

***Faidherbia albida* in the West African semi-arid tropics: proceedings of a workshop, 22-26 Apr 1991, Niamey, Niger.** R.J. Vandenbeldt. (ed.). ISBN 92-9066-220-4. Copublished with the International Centre for Research in Agroforestry (ICRAF).

These proceedings summarize the state of knowledge on the species and provide comprehensive details of ongoing research. Papers are divided into sessions on, botany and distribution, uses, genetics, provenance trials, and vegetative propagation, site effects, silviculture, rhizosphere, and development issues. Includes recommendations for future research and multidisciplinary linkages. A French edition is in preparation.

Botrytis gray mold of chickpea: summary proceedings of the BARI/ICRISAT Working Group Meeting to Discuss Collaborative Research on Botrytis Gray Mold of Chickpea, 4-8 Mar 1991, Joydebpur, Bangladesh. M.P. Haware, D.G. Faris, and C.L.L. Gowda. (eds.) ISBN 92-9066-230-1.

Covers discussion papers on integrated management, epidemiology, and resistance of the disease, and on its occurrence and the problems it causes in India, Bangladesh, and Nepal. Outlines a proposed work plan for the Chickpea Working Group on collaborative research on this serious pathogen.

Managing AGLN crops in rice-based cropping systems: summary proceedings of the Myanmar-AGLN/ICRISAT Workshop and Monitoring Tour, 17-25 Jan 1992. D.G. Faris, C.L.L. Gowda, and Them Han. (eds.). ISBN 92-9066-231-8. Copublished with Myanma Agricultural Service.

Forty two scientists from 11 Asian countries and ICRISAT travelled through the dry zone and delta area of Myanmar to compare the management aspects of groundnut, chickpea, and pigeonpea in rice-based cropping systems. Ways to overcome the constraints to crop production in these systems are discussed.

Proceedings of the Fifth Regional Groundnut Workshop for Southern Africa, 9-12 Mar 1992, Lilongwe, Malawi. R.C. Nageswara Rao, and P. Subrahmanyam. (eds.). ISBN 92-9066-234-4.

Contains papers that reviews various aspects of groundnut research, particularly agronomy and physiology, and summarizes the state of groundnut work in each of the countries represented. The recommendations provide valuable guidelines for regional activities.

Current research on the transformation and regeneration of groundnut (peanut) and utilization of viral genes to induce resistance to virus diseases: summary and recommendations of a meeting, 24-27 Apr 1992, Wageningen Agricultural University, Wageningen, The Netherlands. D.V.R. Reddy, J.P. Moss, and D. McDonald. (eds.). ISBN 92-9066-237-9.

Reports a meeting organized by ICRISAT in cooperation with the Virology Department, Wageningen Agricultural University that included 14 scientists from six countries. Summarizes the state of research and indicates where cooperation could be encouraged.

Groundnut: a global perspective: proceedings of an international workshop, 25-29 Nov 1991, ICRISAT Center, India. S.N. Nigam (ed). ISBN 92-9066-239-5.

Provides a comprehensive record of progress made in groundnut research and production technology in the 1980s. Includes 30 major papers, 100 poster abstracts, and recommendations that outline the future research requirements of the crop.

Plant Material Descriptions

Free leaflets which provide brief descriptions of crop genotypes identified or developed by ICRISAT, to facilitate the identification of cultivars and lines for plant breeding, and promote their wide utilization.

No. 31. **Groundnut Variety ICGV 86590.** ISBN 92-9066-225-5.

No. 32. **Groundnut Elite Germplasm ICGV 86031.** ISBN 92-9066-226-3.

No. 33. **ICC 4958 A Drought Resistant Chickpea.** ISBN 92-9066-232-8

No. 34. **ICGL 1, ICGL 2, ICGL 3, ICGL 4, and ICGL 5 Nonnodulating Groundnut Germplasm Lines.** ISBN 92-9066-235-2.

No. 35. **Pigeonpea Variety ICPL 332.** ISBN 92-9066-240-9.

No. 36. **Genetic Stock Puckered-Leaf Groundnut Mutant ICGL 6.** ISBN 92-9066-277-1

Annual Reports

ICRISAT Report 1991. ISSN 1017-9933.

The ICRISAT Report is the Institute's major public awarness document, intended to reach a wide range of readers. For detailed results of research conducted in 1992, consult Program-level Annual Reports available from Cereals, Legumes and Resource Management Programs, and Genetic Resources Unit, at ICRISAT Center, and from ICRISAT Sahelian Center (Niger) and SADCC/ICRISAT (Zimbabwe).

Cereals Program Annual Report 1991

Legumes Program Annual Report 1991

Resource Management Program Annual Report 1991

Genetic Resources Unit Annual Report 1991

ICRISAT West African Programs Annual Report 1991

Programmes ouest-africains de l'ICRISAT Rapport annuel 1991

Newsletters

SAT News. nos 8, 9, 10, 11. ISSN 1016-4715.

International Arachis Newsletter. no 11. ISSN 1010-5824.

International Chickpea Newsletter. nos 25, 26. ISSN 0255-2506.

International Pigeonpea Newsletter. nos 15, 16. ISSN 0255-786X.

General Audience Publications

ICRISAT in the Media
A compilation of press and other media coverage of ICRISAT events in 1991.

ICRISAT - the First 20 Years.
Les 20 ans de l'ICRISAT.
This commemorative publication, available in English and French, shows the story of ICRISAT's successes and ongoing work through photographs related to each of the four clauses of its mandate, and contains a 'Milestones' section on the major events of the Institute's history.

Indian Prime Minister's Visit to ICRISAT Center
A photographic record of P.V. Narasimha Rao's visit to participate in ICRISAT's 20th Anniversary Celebrations on 31 Aug 1992.

Video

Peas for Prosperity
A 23-minute film about the Asian Development Bank/ICRISAT/Sri Lanka Pigeonpea Project and its effect on farmers and consumers in Sri Lanka. Pigeonpea can be grown in the drier areas of Sri Lanka and could contribute significantly to reducing lentil imports and the proportion of a family's income that is spent on pulses. Present problems and potential solutions are discussed in interviews with farmers and scientists.

ICRISAT Center Administration

James G Ryan, *Australia*, **Director General**
B C Gamini Gunasekera, *Sri Lanka*, Advisor to the Director General for Donor Relations
Bharati K Patel, *Zambia*, Special Assistant to the Director General for Planning
Peter Reavey, *UK*, Special Assistant to the Director General for Educational Affairs
V Balasubramanian, Senior Executive Officer (Director General's Office)
Joyce Gay, Senior Administrative Secretary to the Director General

Internal Audit

Steven D Goode, *USA*, Research Contracts Officer, Manager Internal Audit
A N Venkataswami, Senior Audit Officer

Information Management and Exchange Program

Program Office

R P Eaglesfield, *UK*, Program Leader

Information Services

Susan D Hall, *UK*, Manager Editorial Unit
Eric M McGaw, *USA*, Research Editor
Jugu J Abraham, Senior Editor
V Sadhana, Editor
Deepak Macherla, Editor (*until Jun*)
S M Sinha, Assistant Manager (Art and Production)
Gopal K Guglani, Senior Art Visualizer
T R Kapoor, Senior Supervisor (Composing Unit)
Upendra Ravi, Videographer

Library and Documentation Services

L J Haravu, Manager
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1 Acronyms

ACIAR	Australian Centre for International Agricultural Research
ADB	Asian Development Bank
AfDB	African Development Bank
AGLN	Asian Grain Legume Network
AGLOR	Asian Grain Legumes On-farm Research
AGRHYMET	Centre régional de formation et d'application en agrométéorologie et hydrologie opérationnelle (Niger)
AICORPO	All India Coordinated Research Project on Oilseeds
AICPIP	All India Coordinated Pigeonpea Improvement Project
AIDAB	Australian International Development Assistance Bureau
AOAD	Arab Organization for Agricultural Development (Sudan)
APAU	Andhra Pradesh Agricultural University (India)
AUA	Alemaya University of Agriculture (Ethiopia)
BMZ	Bundesminister für Wirtschaftliche Zusammenarbeit (Germany)
CAAS	Chinese Academy of Agricultural Sciences
CATIE	Centro Agronómico Tropical de Investigación y Enseñanza (Costa Rica)
CGIAR	Consultative Group on International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical (Colombia)
CIDA	Canadian International Development Agency
CIDES	Centre d'information pour le développment économique et social (France)
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo (Mexico)
CIRAD	Centre de coopération internationale en recherche agronomique pour le développement (France)
CLAIS	Comisión Latinoamericana de Investigadores en Sorgo (Guatemala)
CLAN	Cereals and Legumes Asia Network
COMCIAM	Commonwealth Climate Impact Assessment and Management Programme (Australia)
CRIDA	Central Research Institute for Dryland Agriculture (India)
EARCAL	Eastern Africa Regional Cereals and Legumes Program (Kenya)
EARSAM	Eastern Africa Regional Sorghum and Millets Network (Kenya)
EEC	European Economic Community
ELISA	enzyme-linked immunosorbent assay
FAO	Food and Agriculture Organization of the United Nations (Italy)
GRU	Genetic Resources Unit
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit (Germany)
HRDP	Human Resource Development Program
IAR	Institute of Agricultural Research (Ethiopia)
IBPGR	International Board for Plant Genetic Resources (Italy)
ICA	Instituto Colombiano Agropecuario
ICAR	Indian Council of Agricultural Research
ICARDA	International Center for Agricultural Research in the Dry Areas (Syria)
ICIPE	International Centre of Insect Physiology and Ecology (Kenya)
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics (India)
IDRC	International Development Research Centre (Canada)
IER	Institut d'économie rurale (Mali)
IFAD	International Fund for Agricultural Development (Italy)
IFDC	International Fertilizer Development Center (USA)

Acronyms

IFPRI	International Food Policy Research Institute (USA)
IGER	Institute of Grassland and Environmental Research (UK)
IICA	Inter-American Institute for Cooperation in Agriculture (Costa Rica)
IITA	International Institute for Tropical Agriculture (Nigeria)
ILCA	International Livestock Centre for Africa (Ethiopia)
INIFAP	Instituto Nacional de Investigociones Forestales y Agropecuarias (Mexico)
INRAN	Institut national de recherches agronomiques du Niger
INSAH	Institut du Sahel (Mali)
INTSORMIL	USAID Title XII International Sorghum/Millet Collaborative Research Support Program (USA)
IPMDMN	International Pearl Millet Downy Mildew Nursery
IRRI	International Rice Research Institute (Philippines)
ISC	ICRISAT Sahelian Center (Niger)
IVH	intervarietal hybrid
LASIP	Latin American Sorghum Improvement Program (Mexico)
McAbs	monoclonal antibodies
MTP	Medium Term Plan
NBPGR	National Bureau for Plant Genetic Resources (India)
NORAGRIC	Norwegian Centre for International Agricultural Development
NRI	Natural Resources Institute (UK)
ODA	Overseas Development Administration (UK)
PCCMCA	Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos Alimenticios (Panama)
RESADOC	Réseau sahélien d'information et de documentation scientifique et technique (Mali)
ROCAFREMI	Réseau ouest et centre africain de recherche sur le mil (WCAMRN) (Niger)
ROCARS	Réseau ouest et centre africain de recherche sur le sorgho (WCASRN) (Mali)
SACCAR	Southern African Centre for Cooperation in Agricultural Research (Botswana)
SADC	Southern African Development Community
SAFGRAD	Semi-Arid Food Grain Research and Development (Nigeria)
SAT	Semi-Arid Tropics
SATCRIS	Semi-Arid Tropical Crops Information Service
SCRI	Scottish Crop Research Institute (UK)
SDI	selective dissemination of information
SMIP	Sorghum and Millets Improvement Program (Zimbabwe)
SRGB	SADC Regional Gene Bank (Zambia)
SWC	soil and water conservation
TVE	Television Trust for the Environment (UK)
UNDP	United Nations Development Programme (USA)
USAID	United States Agency for International Development (USA)
WANA	West Asia North Africa
WASIP	West African Sorghum Improvement Program (Mali and Nigeria)
WCAMRN	West and Central African Millet Research Network (ROCAFREMI) (Niger)
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