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ICRISAT 1972-97

ICRISAT

Report 1996

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.

ICRISAT's Mission

Through international research and related activities, and in partnership with national research systems, to contribute to sustainable improvements in the productivity of agriculture in the semi-arid tropics (plus other countries in which ICRISAT's mandate crops have relevance) in ways that enhance nutrition and well-being, especially of low-income people.

(96)

ICRISAT
Report 1996

International Crops Research Institute for the Semi-Arid Tropics

Patancheru 502 324, Andhra Pradesh, India

1997

The King Baudouin Award of the Consultative Group on International Agricultural Research

Presented to

The International Crops Research Institute for the Semi-Arid Tropics—ICRISAT

October 28, 1996

To recognize outstanding achievement

in the development of disease-resistant,

yield-increasing pearl millet

in collaboration with advanced institutions

and national research programs

Donald Winkelmann
Chair, Technical Advisory Committee

[signature]
Chairman, CGIAR

In 1996, ICRISAT won international recognition for its scientific achievements.

Crowning the year was a "double first" for the Institute – two awards made at International Centers Week, the annual gathering of the Consultative Group on International Agricultural Research (CGIAR) to which ICRISAT belongs. For the first time, ICRISAT won the much coveted King Baudouin Award, in recognition of its "outstanding achievements in the development of disease-resistant, yield-increasing pearl millet in collaboration with advanced institutions and national research programs". The other award was a new one inaugurated by the Chairman of the CGIAR to recognize outstanding achievements on the part of locally recruited professionals at the Centers. This came to Dr S B Sharma, a senior scientist in our Crop Protection Division, for his work on nematode parasites of food legumes.

The excellence of ICRISAT's research was also recognized by the Institute's Fourth External Program and Management Review (EPMR) Panel, which stated that "ICRISAT has a long list of achievements to its credit", and hailed its "enduring and conspicuous successes" in the three major research areas of germplasm conservation and enhancement, crop improvement, and natural resources management. The Panel pointed to the mounting evidence that improved crop varieties derived from ICRISAT materials are now benefiting resource-poor farmers. It concluded that ICRISAT had a "vital continuing role in the semi-arid tropics", especially in view of its increasing impact on the lives of poor people.

We may justifiably claim that ICRISAT's scientific health could scarcely be better. Would that we could say the same for our financial health! It is a sad paradox that, in 1996, as the evidence of our impact grew daily stronger, our funding situation steadily deteriorated. Proposed changes in World Bank funding mechanisms,

CGIAR

S B Sharma receiving the "Excellence in Science" Award from CGIAR Chairman Ismail Serageldin.

together with inflation, are compounding reductions made by a number of donors.

Our reduced expectations for 1997 have forced hard choices on us. But we are seeking to create new opportunities out of adversity. We are pursuing efficiency gains through stronger partnerships with a wider range of organizations, especially non-governmental ones. By moving upstream in the research spectrum and relinquishing the development of finished products, we are saving resources while bringing about a quantum leap in impact, notably in India. By shifting to project-based research management, we have created a more transparent ICRISAT with which our stakeholders can more easily identify. Above all, we know that we have to become more entrepreneurial in our dealings with prospective donors. That is why we have given greater emphasis to the packaging of our agreed agenda projects and marketing them to specific agencies.

Amidst the financial doom and gloom, there are some bright spots. No less than three new donors agreed to support our work in 1996. Among them was the Common Fund for Commodities (CFC), headquartered in Amsterdam, which has undertaken to support a part of our research on groundnut germplasm in western Africa and Latin America. Another newcomer is the government of the Islamic Republic of Iran. We are especially grateful to a third donor, Denmark, who provided US$ 2.165 m in their initial year of support.

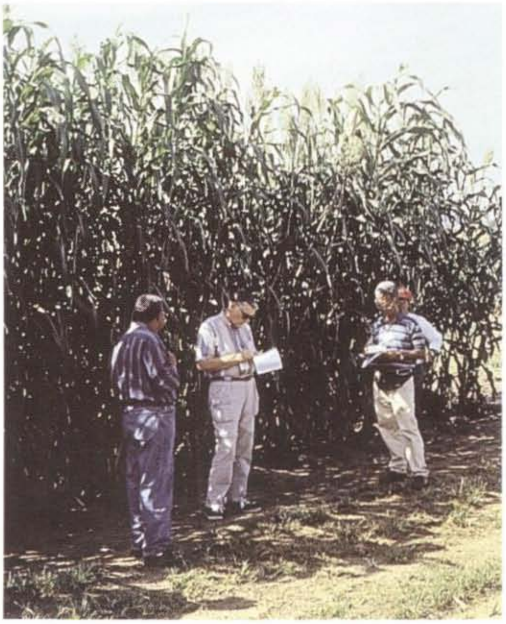
Several existing donors extended a helping hand to ICRISAT in 1996 by increasing their contributions. These included Australia, which increased its support from US$ 0.522 m in 1995 to US$ 0.620 m in 1996, France from US$ 0.292 m to US$ 0.804 m and India from US$ 0.188 m to US$ 0.587 m. The Republic of Korea revived its support to ICRISAT in 1996 after a gap of a few years.

Planning ahead is difficult in times of financial uncertainty. At such times it is all the more important to


Suresh Pande

Europe's Common Fund for Commodities will fund ICRISAT's groundnut germplasm screening work in western Africa canvass the opinions of stakeholders and to build a consensus on the best way forward. To set the priorities for our 1998–2000 Medium-Term Plan (MTP), we convened a special working group mandated to consult widely both within and outside the Institute. The group sent questionnaires to national partners, assembled focus groups for specific topics, considered the strategic inputs made by the CGIAR's Technical Advisory Committee (TAC), Center-Commissioned External Reviews (CCERs), and other sources of expertise, and read copiously! These activities were complemented by visits to national partners and regional fora in Asia and Africa. As the consultation process unfolded, we were heartened by the reassurance we received from our partners that ICRISAT's intended future directions are basically the right ones. Yet the process also revealed the need for significant changes of emphasis in our program, mainly reflecting national perceptions of need and the chances of success. The results of the consultation exercise are given in full in the Governing Board-approved draft of our MTP, which has now been presented to TAC.

A key feature of the MTP is its departure from previous approaches to fund raising. In keeping with the new entrepreneurial and partnership spirit of the CGIAR, we are encouraging our scientists to be more pro-active in pursuing funding opportunities jointly with national research groups and match them to the special interests of donors wherever possible. We will also explore nontraditional donor sources such as the private sector, non-governmental organizations (NGOs), and the governments of developing countries.


R Tabo

The EPMR team at work in Bagauda, northern Nigeria

An important source of inputs to the MTP was the Fourth EPMR of ICRISAT, which submitted its report to TAC and the CGIAR in December 1996. Here is not the place to give a detailed account of the review's many perceptive insights, nor of its detailed recommendations and suggestions. But we will take this opportunity to respond to the Panel's bold and imaginative thinking with regard to ICRISAT's future.

The EPMR proposed a new model for the Institute, in which strategic and global germplasm research would be based at ICRISAT Asia Center while research on the management of natural resources would be concentrated mainly in Africa. A smaller,

The EPMR recommended that strategic germplasm research should be the primary focus at the Asia Center.

more focused ICRISAT would enhance its cost-effectiveness through improved research partnerships and networks.

The Governing Board has given serious consideration to this model and endorsed its general direction. We accept the need to move upstream in germplasm research. Indeed, we have already begun to do so, and our MTP proposes that we accelerate this process. We agree that the main constraint to sustainable productivity increases in SAT Africa is now the management of natural resources, notably soil fertility. And we acknowledge the need for a tighter focus on a clearly defined operational mandate.

Nevertheless, we have reservations in accepting the model too literally. Africa has a continuing need for ICRISAT's direct involvement in applied germplasm research and technology exchange. In addition, there is alarming evidence of natural resource degradation in parts of Asia, burdened as this region is with high population densities and pockets of extreme poverty. Concentrating germplasm research in Asia and resource management research in Africa would make it harder to address these needs. It might also impair the integration of these complementary dimensions of agricultural research, and could even threaten to break the Institute into two over the longer term.

The future of our work in both Africa and Asia was discussed by the many review teams that visited us in 1996. In preparation for the EPMR, we commissioned three Center-Commissioned External Reviews (CCERs) in 1996, two for Africa and one for Asia. These followed the two in 1995. CCERs are a recent innovation by the CGIAR, intended to facilitate the work of the EPMR teams and their interaction with Center Boards, management, and staff. However, we have to confess that neither we nor our colleagues noticed any lightening of the load on our shoulders during what remained a highly intensive EPMR process!

Three strategic studies commissioned by the CGIAR received our attention during the year. The most important of these for ICRISAT was the study of priorities and strategies for resource allocation during 1998–2000. ICRISAT noted close congruence between this study and the conclusions of its Fourth EPMR, a convergence of ideas that provided particularly useful guidance during a time of budgetary uncertainty. The other two studies focused on research priorities for marginal lands and on harvest and postharvest research.

One concern of the EPMR was that ICRISAT tends to undersell its achievements. If that is the case, we are sure readers will not mind our dwelling briefly on two areas of our work in which we take a special pride. These areas have the added advantage of demonstrating the greater efficiency we are achieving, despite cuts in funding, through our relationships with a broadening range of traditional and nontraditional partners.

The figure on page 8 plots, for each of our mandate commodities, the number of new varieties released each year from 1975 to 1996. It shows how the pace steadily quickened throughout the 1980s, reaching 25–30 per year by the early 1990s. Since then there has been a further spurt, with the estimated total number of releases rising from 166 in 1992 to more than 365 in 1996, an increase of about 120% in just 4 years. The increased productivity reflects both the contribution of ICRISAT's breeders and the growing capacity of national institutions to use genetic materials supplied by ICRISAT from the genebank at the Asia Center, as illustrated by the table below. It is partly due to our investments in human resource development, and it also reflects a rapid increase in the use of ICRISAT germplasm made by the private sector. In countries such as India, private-sector releases developed from parents supplied by ICRISAT have escalated in the 1990s. If this is a glimpse of things to come in less-developed Asian countries and in Africa, our productivity will look even more impressive a few years from now.

Assembly and distribution of germplasm

	Collection, 31 Dec 1996		Samples distributed 1972–96			
Crop	Accessions	Countries of origin	ICRISAT	India	Rest of the world	Recipient countries
Sorghum	36 242	90	228 019	120 210	136 886	98
Pearl millet	21 264	50	33 325	61 792	32 508	75
Chickpea	17 250	44	148 278	57 069	50 393	81
Pigeonpea	13 015	72	72 848	39 623	18 327	102
Groundnut	14 732	92	56 055	38 272	42 267	88
Minor millets	9 255	43	0	24 375	17 860	49
Total	**111 758**		**538 525**	**341 341**	**298 241**	

The second area is ICRISAT's participation in the evolution of a new model of technology dissemination in Africa. This region has so far lagged behind Asia in transferring new crop varieties to farmers' fields. The reasons for this are complex, but in several countries a major factor has been civil war. Besides claiming many human victims and devastating the rural economy, these wars have often destroyed not only the infrastructure for research but also the raw materials for it – the national germplasm collection.

Once the fighting is over, the awesome task of reconstruction begins. First in Rwanda, then in Mozambique, Eritrea, and Angola, ICRISAT has worked with national research institutions, extension services, private companies, NGOs, and its sister Centers in the CGIAR to multiply and disseminate the seeds of improved crop varieties adapted to the production environments of these countries. Placed in the hands of farmers returning to their land, these seeds have proved invaluable in kick-starting the rural economy. ICRISAT provided duplicates of the original germplasm collections to refurbish national germplasm collections and to relaunch on-station and on-farm research. At the same time, training and rehabilitation initiatives have helped to restore the physical and human capital of the research systems.

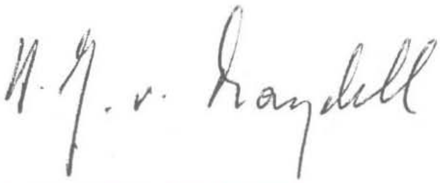
E M McGaw

Relaunching the rural economy. Farmers return to their land in Rwanda after the social unrest.

All the partners in these efforts have learned from one another. The result is a shared conviction that new technological options can make a difference to the lives of the rural poor, and a shared determination to deliver them – fast! The combination of the technical expertise of the Centers and the grass-roots organizational skills of the NGOs has proved especially powerful. Evolving alongside – and sometimes out of – these short-term rescue operations are longer-term collaborative arrangements to multiply and disseminate seed. These arrangements are now well established in almost every country of southern and eastern Africa, and appear to be taking shape in western Africa too. Often, they involve new and imaginative ways of working that emerge from within local communities and tap their special strengths.

ICRISAT has an immensely challenging mission – to end poverty, hunger, and environmental degradation in some of the world's most difficult agricultural environments. Let us close by thanking our colleagues at ICRISAT and on the Governing Board, and our partners around the world, for all they have done, and will do, to fulfil that mission. As the contents of this Report demonstrate, we are well on the way to success.

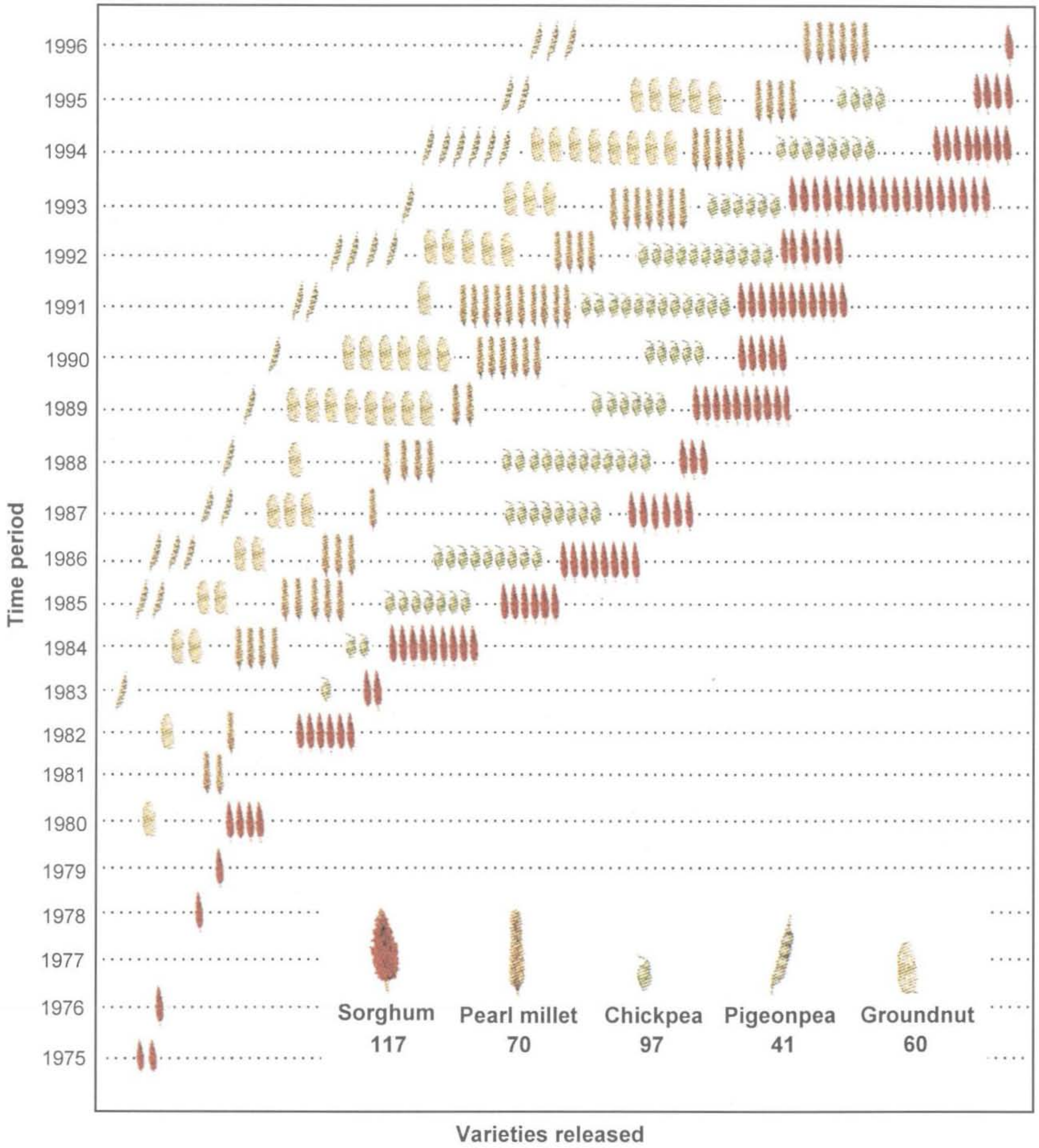
R A Naidu



Hans-Jürgen von Maydell
Chairman, Governing Board

James G Ryan
Director General

Distribution of ICRISAT and national varietal releases, 1975–96

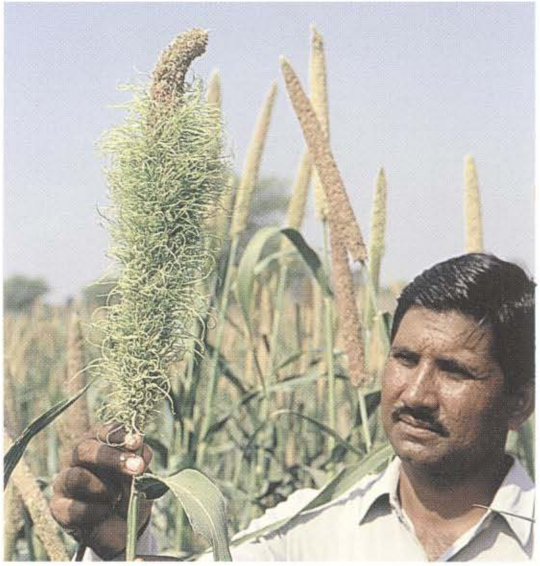


An impact beyond our dreams

School children are given a free egg for lunch each day, smallholder dairy production is up, and the private sector is selling hybrids of what was once a poor man's crop. These are some of the unexpected benefits from research on pearl millet. Work on this crop won ICRISAT the 1996 King Baudouin Award.

Award-winning research

The award, made bi-annually by the Technical Advisory Committee (TAC) of the Consultative Group on International Agricultural Research (CGIAR), came in recognition of ICRISAT's collaboration with national programs in the development of high-yielding pearl millet cultivars resistant to major diseases, especially downy mildew. The fact that the Institute had documented the impact of this research helped tip the balance of TAC's opinion in ICRISAT's favor.


C T Hash

Downy mildew is the most widespread disease of pearl millet in the SAT.

Impact studies at ICRISAT are the responsibility of special multidisciplinary teams that work closely with national scientists. In 1994, teams began studying the adoption of new varieties in India's major pearl millet growing areas, including parts of Gujarat, Maharashtra, Rajasthan, and Tamil Nadu.

Adoption is furthest advanced in Gujarat and western Maharashtra, where improved cultivars are now grown on over 90% of the pearl millet area. The reasons for this high adoption rate lie in these states' relatively high-potential soil and water resources, coupled with strong public- and private-sector seed and input delivery systems.

Towards the other end of the spectrum lies eastern Rajasthan, where environmental conditions are tougher and private-sector involvement in seed dissemination is more recent. In this region improved materials account for around 30% of the pearl millet area.

Adoption is lowest of all in central and western Rajasthan. Here, on the fringes of the desert, adapted improved materials are hard to come by and only a few farmers grow very small areas of them. A detailed impact assessment has yet to be carried out in this region.

C T Hash

Looking at impact. National and ICRISAT scientists interact closely with farmers to study the adoption of new varieties.

Even in relatively high-potential Gujarat and western Maharashtra, most farmers have adopted new varieties without greatly changing their management practices. Those growing the crop mainly for subsistence apply little fertilizer, while those producing it for sale in better environments tend to use more. Yields in these two states averaged 1000 to 2000 kg ha^{-1} for improved varieties, a gain of approximately 50% over farmers' existing varieties. These figures can be put in perspective by recalling the yields of 200–400 kg ha^{-1}, recorded in the 1960s and 1970s for farmers growing local landraces.

Coupled with resistance to downy mildew, the increased yields have brought greater food security to millions of resource-poor farmers in drought-prone areas. In addition, many farmers now have a surplus to sell, with the result that their incomes have risen. In India as a whole, ICRISAT's socioeconomists estimate that the annual returns to pearl millet farmers from cultivating new varieties amount to a staggering US$ 54 million. That's about double the annual budget for the whole of ICRISAT, and over 12 times the annual cost of the Institute's pearl millet research!

The private sector moves in

Ask farmers in eastern Rajasthan what variety they have sown and the chances are they'll give you a vague answer – something along the lines of "Well, I bought it off a trader". Farmers in Maharashtra or Gujarat, on the other hand, are more likely to quote a series of letters and numbers denoting their awareness of the variety's precise identity and origin.

Their answers symbolize the different degrees to which the private sector has moved into the seed business in the two states – a factor that, more than anything else, explains farmers' access to new varieties. In Rajasthan, private-sector involvement is at an early stage and farmers have little access. In Gujarat and

Maharashtra, farmers have become sophisticated users of a wide range of improved materials supplied mainly by the private sector.

In Maharashtra, the role of the private sector has increased dramatically during the 1990s. Whereas farmers in the late 1980s obtained most of their improved materials from public-sector research and extension organizations, they now obtain nearly half from private seed companies (Fig. 1). And the share of the seed companies looks set to grow still further.

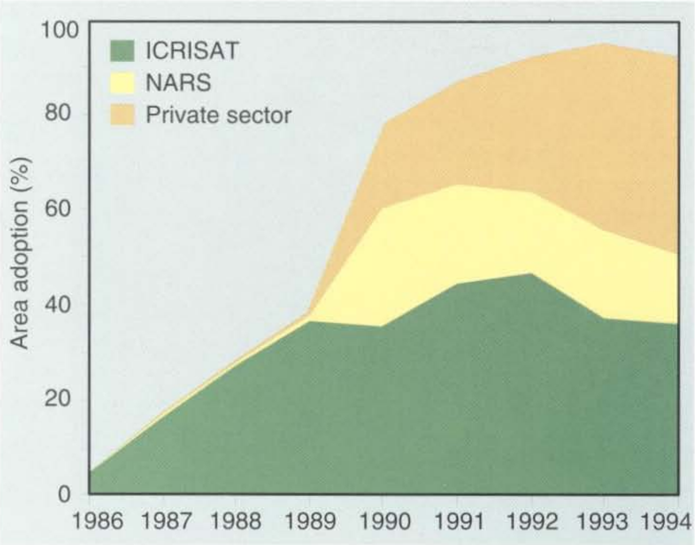


Figure 1. Shares of ICRISAT, national organizations, and the private sector in the dissemination of improved pearl millet materials in Maharashtra, 1986–94.

The expansion of private-sector research in the second half of the 1980s has brought a wave of new materials to farmers. Most of these materials are hybrids developed from parents or breeding lines supplied by ICRISAT and national research institutions. Farmers have used them to replace the few improved cultivars grown previously, returning regularly to seed shops for fresh supplies of seed.

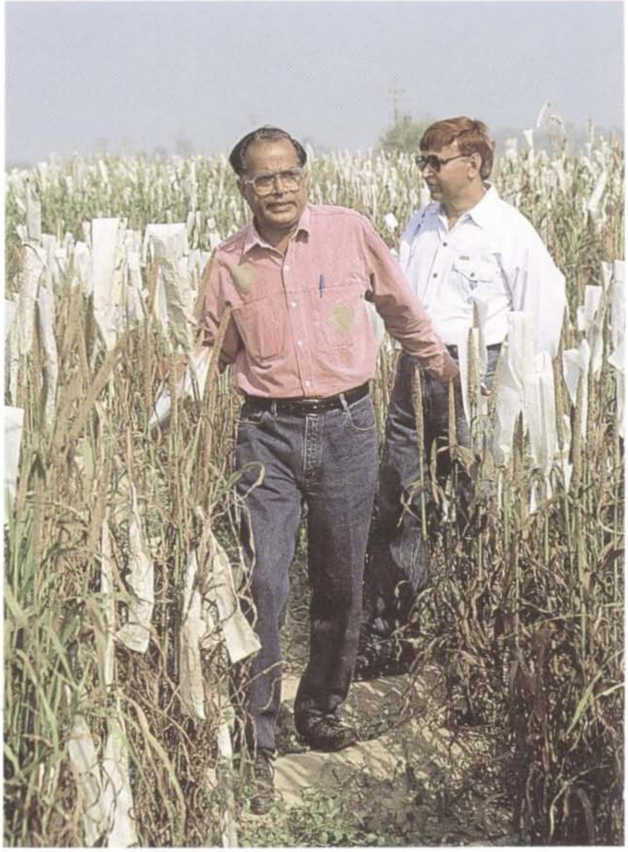
Thus the increased commitment of the private sector to research has allowed ICRISAT to become a major supplier of intermediate products, in keeping with its intention to move upstream in the research spectrum. This is an important factor explaining the considerable impact achieved in recent years.

In central and western Rajasthan, private-sector involvement is still at a much lower level. In future the vacuum may be partly filled by non-governmental organizations (NGOs), some of which are showing an interest in becoming seed suppliers as a result of their contact with ICRISAT.

What happened to biodiversity?

Critics of formal research claim that biodiversity is lost when new varieties replace traditional landraces. The studies showed that this isn't always true.

On-farm surveys revealed that the early stages of adoption are almost invariably accompanied by a gain in biodiversity, not a loss. Farmers are suspicious of new types of seed, growing them on only a small proportion of their land or mixing them with



National programs provide vital support – breeding hybrid seed parent progenies in national program nurseries.

their own seed in the first few seasons. During this period they retain their full set of existing varieties.

In the more marginal farming areas, farmers subsequently increase the amount of land devoted to new varieties only slowly, so the gain in biodiversity lasts well into the adoption process, or even right the way through it. In eastern Rajasthan, for example, around 50% of farmers have adopted improved varieties, but these cover only 30% of the area sown to the crop.

In higher-potential areas such as Maharashtra and Gujarat, adoption is far more pervasive and the situation is more complex. The use of hybrids incurs a loss of diversity at field level, as all the plants of a given crop are genetically uniform. But at the level of the production system diversity is increasing again, having reached its narrowest a decade ago: the hybrids grown now number 15 or more, compared to the two or three that were prevalent in the mid-1980s. This "hourglass effect" is typical of rapidly modernizing systems: when a few new varieties enter the system and are taken up by large numbers of farmers, diversity may be sharply reduced. Thereafter, as the flow of new releases continues, it starts to broaden again.

Much of the new material in farmers' fields is of western African origin, and has thus enhanced biodiversity. Scientists discovered the *iniadi* germplasm of northern Togo and Ghana in the early 1980s. In both Asia and Africa, these short-duration, large-seeded lines have proved immensely valuable in improving both the yield and the yield stability of the crop, as well as its appeal to consumers. But it's now time for a change: in the interests of further broadening the genetic base of future new varieties, breeders are turning their attention to other underexploited germplasm.

Farmers play safe

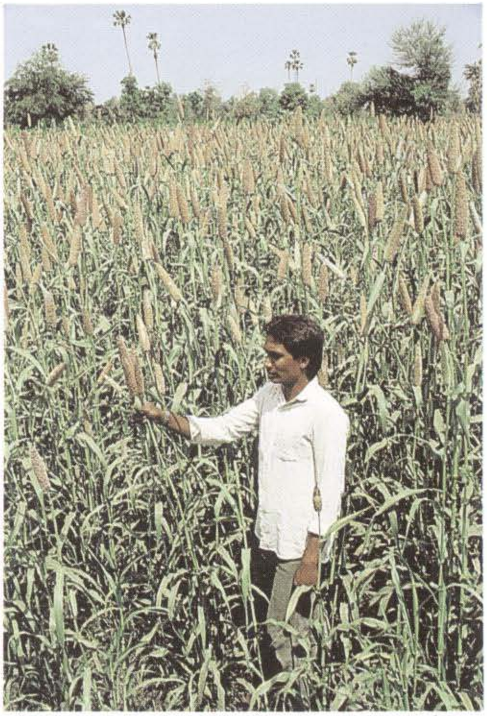
Farmers incorporate new varieties into their cropping systems in such a way as to minimize risk while increasing productivity whenever possible.

In western and central Rajasthan, they sow improved varieties of relatively long duration if rains come early, following these with their traditional shorter-duration varieties over the next month. If the monsoon arrives late or the first crop fails to emerge, only the shorter-duration varieties are sown. In this case, the new germplasm helps farmers grow more in a good year, while the old continues to stabilize the system and reduce risk.

Farmers follow exactly the same strategy when the improved germplasm is short-duration. In eastern Rajasthan and western Uttar Pradesh, for example, they sow their traditional long-duration varieties first, then improved short-duration ones. Here it is the new germplasm that confers greater system stability, accompanied by a moderate increase in average yields.

Where irrigation is available or good rains establish early, the conditions for production are less risky. Here farmers may sow new, very short-duration varieties early in the season, in the hope of being able to double-crop.

Around 30% of Maharashtra's pearl millet area continues to be sown to an improved open-pollinated variety, ICTP 8203. This is a short-duration, bold-seeded variety that yields about 10% less than most hybrids, but it has one great advantage: its inherent genetic variability provides better protection against downy mildew disease. Farmers in Maharashtra are anxious not to repeat the experiences of the 1980s, when many faced ruin as downy mildew epidemics repeatedly swept across the state and decimated yields of hybrids.



C T Hash

The improved, open-pollinated pearl millet variety ICTP 8203 offers protection against downy mildew.

Implications for seed systems

The continuing diversity in farmers' fields has radical implications for national seed systems.

Where sowing is staggered, long- and short-duration varieties flower at roughly the same time, leading to outcrossing. In the following year, yields may actually

The public sector takes over breeder seed production responsibilities.

improve as a result of hybrid vigor. But thereafter seed quality steadily deteriorates and production starts to decline. Landrace quality suffers just as much as that of hybrids.

If farmers' risk-aversion strategies are to work, they need periodic access to fresh seed of both types. Best placed to ensure the future supply of hybrids is the private sector, whose share of the market is already increasing rapidly. Public-sector services and non-governmental organizations (NGOs) have been involved in the multiplication and dissemination of both open-pollinated varieties and hybrids. In future, while gradually relinquishing their role in hybrid dissemination, they may need to take on the task of supplying good quality seed of adapted landraces.

A changing image

The conventional image of pearl millet is of a crop grown only for subsistence by poor people in areas where nothing else will survive. But the crop is no longer just that. Through their research, ICRISAT and its national partners have enabled farmers to produce marketable surpluses destined for a broader range of end uses.

Tamil Nadu provides a special case of this process at work. Here demand for pearl millet as a staple food fell as people switched to wheat and rice, the consumer prices of which are heavily subsidized. This drove prices down – until the crop became cheaper than maize and began to substitute for it in poultry rations.

As demand for eggs and chicken rose, the intensive poultry sector started to expand rapidly, and pearl millet prices rose again. The crop retains its competitive edge because, unlike maize, it can be grown without irrigation and does well in less fertile upland areas. Pearl millet still contributes to food security, but in a different form: the state government now provides school children with a free egg for their lunch each day.

In Gujarat, pearl millet is even being grown under irrigation during the dry season. Farmers in this water-short state switched out of groundnut and sorghum and into short-duration pearl millet when they realized that this would mature faster and consume less water. Time to maturity is vital, because a second crop can be produced, thus providing more food for hungry dairy buffaloes during a period when other feed sources are scarce. Gujarat is home to the famous Anand smallholder dairying scheme, that has been a major beneficiary of the switch.

Like cassava in Latin America, pearl millet in Asia is crossing the boundary that separates subsistence and cash crops. In fact, a subsistence crop *becomes* a cash crop as soon as farmers have a surplus to sell. And new uses for the crop emerge once human food needs have been met.

No room for complacency

There is no doubt that research on pearl millet in India has had a tremendous impact. But producers in the very poorest and most marginal areas – such as western Rajasthan – have yet to benefit fully. In India as in Africa, efforts must now redouble to bring the benefits of science to those "living at the edge".

E Weltzien-Rattunde

Impoverished families in marginal areas have yet to reap the full benefits of agricultural research.

Building capacity

Besides studying impact directly, ICRISAT aims to build national capacity for impact assessment.

Trainees from national institutions spend short periods at ICRISAT studying the basic principles and methods before going out into the field to learn how to apply them. At the end of the training period, ICRISAT socioeconomists ask them to come up with a proposal for collaborative research.

The trainees start their research on return to their home institution. They keep in touch with ICRISAT researchers through follow-up missions, workshops, and other meetings. In this way the ex-trainees form a slowly expanding informal network of fully fledged professionals.

Western Africa's catching up

With its more difficult environments and less well developed links between institutions, western Africa has lagged behind Asia and the rest of Africa in technology development and dissemination. Now the region is beginning to catch up – as the recent progress in sorghum and pearl millet in Nigeria shows.

Farmers' interest quickens

Linger as you stroll past Alhaji Zubairu Adamu's hut, and you are likely to get a suspicious glare from its occupant. Adamu lives near Bichi, on the main road north from Kano into Nigeria's Sahelian zone. When neighbors saw that he had a beautiful stand of mature pearl millet while their own crop was still at the flowering stage, they became envious – and curious. Several tried to steal seed, as also did passing motorists who had spotted the crop as they drove by. "I had to fight people off", says Adamu, glancing anxiously out of his doorway.

Adamu is one of a growing number of farmers in northern Nigeria participating in the on-farm testing of new sorghum and pearl millet materials developed by ICRISAT and its partners. The pearl millet variety that had excited so much unwelcome attention was GB 8735, a short-stemmed, early-maturing plant with large gray grain that goes down well with consumers. Most of the farmers around Bichi grow traditional medium-duration varieties and have had little previous exposure to early-maturing types.

R Tabo

The Adamus were delighted with their early pearl millet crop.

That's likely to change soon, as the on-farm research program expands. During the 1996 season, farmers on a visit to the Minjibir research station went live on national television to express their enthusiasm for the variety. ICRISAT scientists watched their screens with interest as farmers praised the plant's earliness and spoke of their eagerness to obtain more seed. In response, they teamed up with the Lake Chad Research Institute (LCRI), which has the national mandate for pearl millet research, to produce nearly a quarter of a tonne of seed for on-farm testing in nine northern Nigerian states during the 1997 season.

No less in demand is seed of two recently released sorghum varieties, ICSV 111 and ICSV 400. Again, these are short-stemmed, early-maturing plants that are new to farmers accustomed to growing traditional long-duration guinea types. They are highly popular for making a traditional porridge known as *kamu*.

R Tabo

On-farm millet trials.

These are signs of changing times in western Africa. In response to continuing drought and closer integration with today's more open market economies, farmers' interest in new technologies that can at once safeguard and increase their harvests is quickening. At the same time, the organizations responsible for technology development and dissemination are starting to work together to deliver the new crop varieties that farmers want.

"Please release me..."

The fruits of collaboration between the Institute of Agricultural Research (IAR) and ICRISAT – ICSV 111 and ICS 400 – were two of four open-pollinated sorghum varieties released by the Nigerian Government in August 1996. This achievement was matched by an equally impressive clutch of hybrids, bringing the total of new sorghum releases in Nigeria that year to eight.

New pearl millet releases are likely to follow soon. With pressure from farmers building rapidly, GB 8735 is clearly a technology begging for widespread dissemination.


R Tabo
Nigeria's Institute of Agricultural Research is ICRISAT's partner in sorghum breeding.

Getting official blessing for new crop varieties in Nigeria used to be a lengthy process. But the country has recently simplified its testing system by dropping the requirement for varietal trials at State level. This has reduced the time taken to approve new releases by around 25%.

Much of the new material being tested in Nigeria is attracting attention further afield. The improved sorghum ICSV 111, for example, has already been released by Ghana and is in its third year of on-farm testing in Benin. And the pearl millet variety GB 8735 has proved highly popular with farmers in Mauritania and Chad, the two countries where it has already been released.

Dynamic systems

Northern Nigeria's production systems are in flux, with farmers responding quickly to market signals and alterations in the supply of inputs. Given the long lead-in time required to develop new crop varieties, it is vital that researchers keep abreast of such changes.

The man who knows most on this subject at present is undoubtedly Professor A Ogunbile, until recently leader of IAR's farming systems research team. Under ICRISAT's new visiting scientist program, he has just completed a 1-year study to re-characterize the region's production systems, and in particular the "benchmark" sites of Bichi and Bebebji, where IAR and ICRISAT plan to test new technology options with farmers.

The study's most important achievement was to quantify a major shift in production in recent years – away from maize and into sorghum and pearl millet. Behind the shift is a chronic shortage of fertilizers, which farmers recognize as essential for obtaining high yields in maize. The study highlighted the importance of overcoming problems in the marketing and distribution of commercial fertilizers, as well as the vital role played by legumes in maintaining soil fertility.

The plot thickens

Farmers in northern Nigeria are efficient users of the region's limited rainfall. If early rains come in May they sow millet, widely spaced to leave room for other crops or to cope with drought if the rains peter out. In June, sorghum and groundnut are sown amongst the millet, taking up much of the extra space. Finally, in late July or early August the farmers put in a cowpea crop. If the rains hold, they obtain both fodder and food; if not, then fodder alone. Thus crop density increases as the rains intensify, with the field reaching its fullest at the height of the rains, in August.

In such a system, shortening the duration of one of the earlier-sown components increases the productivity of the whole system. For instance, by sowing a short-duration pearl millet such as GB 8735, farmers can bring forward the sowing date of cowpea and sow more of it, having harvested the pearl millet first. The earlier sowing of cowpea increases the chances of obtaining grain to feed people in addition to haulms for livestock.

ICRISAT and IAR are now testing a range of new short-duration cereal and legume cultivars in several intercropping and relay patterns and rotations, with the aim of developing more stable and sustainable systems. Among the legume materials are improved cowpea and soybean varieties developed by the Ibadan-based International Institute of Tropical Agriculture (IITA), as well as groundnut and pigeonpea materials from ICRISAT.

New partnerships

As the drive to develop and extend technology to farmers intensifies, the institutions involved are forging new ways of working together to derive maximum impact from limited resources.

Take ICRISAT's partnership with LCRI, for example. This takes a simple but novel form that both sides have found conducive to a productive and harmonious relationship. Instead of keeping separate breeding programs, the two institutions agreed to pool their pearl millet germplasm in a single set of collaborative trials. Any technology developed is thus a joint product, the credit for which is shared.

The relationship with IAR has so far followed a more conventional approach in which each partner has maintained a separate program. But there are now plans to launch joint activities in identifying parents and making crosses.

Following a trend already well established in southern and eastern Africa, non-governmental organizations (NGOs) and private-sector companies are joining forces with public-sector research and extension services to test the new technology options on farmers' fields and to multiply and disseminate seed.

It was a public-sector organization, the Kano State Agricultural and Rural Development Authority (KNARDA), that took the lead in the current push to expand on-farm research. When farmers visited ICRISAT's Bagauda Research Station in 1995, they asked that the demonstrations should be moved to their own fields. KNARDA responded promptly, organizing the testing of 10 pearl millets and 10 sorghums in three villages the next season. With funding from LCRI, a further eight state authorities will join the on-farm testing program in 1997.

Also throwing its weight behind the program is the largest international NGO currently working in Nigeria, Sasakawa-Global 2000. This organization was already dispensing seeds of hybrid maize and wheat when it began receiving requests from farmers for improved sorghums and pearl millets. An offer from ICRISAT to provide breeders' seed and advice was sufficient to persuade them to become involved. At first they stuck to hybrid sorghums only, since this was where their experience lay. But they have now agreed to multiply and disseminate open-pollinating varieties as well.

Private-sector involvement has followed a similar path. Nigeria's leading seed company, Premier Seeds Ltd, was at first willing to stock only hybrid sorghums, in line with the conventional wisdom that the demand for open-pollinated varieties was too low and unpredictable to be worth its while. Now, however, the company has decided to multiply and disseminate the two most popular open-pollinated varieties, ICSV 111 and ICSV 400.

Spillover with froth

When ICRISAT and IAR researchers bred the improved early-maturing sorghum variety ICSV 400, they were aiming to contribute to food production. And indeed, the variety's large white grains have made it a hit with subsistence farmers, who say it makes first-class flour.

What the researchers didn't know was that the grains also contained the enzyme beta-amylase, a vital ingredient for malting. The discovery was made by Guinness

Breweries Ltd, who subjected a few seeds to chemical analysis in their laboratory. The company had regularly requested seeds of new varieties from ICRISAT and its partners as part of its search for substitutes for barley, imports of which were banned by the Nigerian Government in the 1980s.

ICSV 400 proved to be just the variety that Guinness needed for its contract growers in the dry northern states, where it is now being widely grown. The company has since approached ICRISAT for help in developing malting varieties suitable for wetter areas. On condition that Guinness fund the work, the Institute has agreed to supply seed of eight F_2 populations for further selection and testing.

Small amounts of ICSV 400 are already an ingredient of several kinds of lager, and research is in progress to increase the proportion used. ICRISAT's scientists are hoping to be invited to sample the results, courtesy of Guinness Breweries Ltd of course. What better way to celebrate this uniquely refreshing example of spillover from the public to the private sector?

Providing food and drink – ICSV 400 makes first-class flour, but its grains also contain beta-amylase, an enzyme vital for malting.

Kenya's Powerhouse

"Financially we are weak, but we are strong in spirit through working together". With these words Diana Nzomo, leader of the Ivuso ya Manyatta Women's Group, epitomizes the culture of community action that is helping some of Kenya's poorest people improve their lot. As ICRISAT's scientists have found, a little help from the outside goes a long way in strengthening such groups.

An unusual enterprise

Cakes made by the women of Ivuso have become a regular fixture at weddings and birthday parties in Makindu town. The women also do a nice line in biscuits, which at US$ 0.18 a bag have become a popular snack in the neighborhood.


S Chater

Diana Nzomo at the bakery.

The cakes and biscuits are unusual in that they contain a high proportion of sorghum or millet flour instead of the conventional wheat. The sorghum flour is made from the short-duration sorghum variety KARI Mtama 1. This was released by the Kenya Government in 1995, having been selected by the Kenya Agricultural Research Institute (KARI) from a nursery provided by ICRISAT. Also used is the short-duration pearl millet variety ICMV 221. This too was developed by ICRISAT and introduced to Kenya in 1992.

The women have a strong sense of ownership of their small but flourishing business. That isn't surprising, since nearly all that surrounds them in their workplace is the fruit of their own labor. They began by making the bricks and tiles, then built the two-roomed building that now serves them as both processing unit and shop. In 1995, an outside oven was added and the group began baking.

As if building and running the bakery were not enough, the women are also busy farmers. This year, 15 Ivuso members are growing KARI Mtama 1 on their own farms and will sell the harvest to the bakery. Members are also multiplying the seed of this and other improved varieties for sale to other farmers.

Moving out of maize

Agriculture is relatively recent in Kenya's semi-arid midlands. Driven down from the highlands by rising population pressure, new settlers have cleared the bush to cultivate land many consider too dry for cropping. Most of the former highlanders were raised on maize, a crop they still prefer to eat and which many still attempt to grow. But owing to low and erratic rainfall maize is too risky here, and there is a great need to promote better adapted grain crops to take its place.

S Chater

Kenya's midlands: population is rising as families move down from the highlands.

The most obvious candidates are sorghum and pearl millet. At Kiboko and other locations, KARI and ICRISAT are screening and testing new short-duration varieties of these crops to complement those already released. The researchers gauge the acceptability of their products in the surrounding farming community through on-farm research. Participating in this process are several local women's groups, including Ivuso. By multiplying and disseminating seed, the groups have become active promoters of the new technology.

The farmers have found they can rely on the new varieties to produce a yield in difficult years when other crops fail. The challenge is to broaden the appeal of sorghum and millet to consumers hooked on maize. That's why the Ivuso women started experimenting with biscuits and cakes.

To make acceptable baked products, flour from sorghum and millet must be finely ground. This is difficult to achieve using traditional milling techniques. Dissatisfied with their dependence on external millers for this crucial operation, the Ivuso women turned to ICRISAT for help in making them self-sufficient.

Enter the United States Agency for International Development (USAID), which in 1996 launched a project to explore new ways of promoting technology

S Chater

Many farmers sow maize in areas better suited to sorghum or pearl millet.

dissemination in eastern Africa. Under the project, non-governmental organizations (NGOs), including women's groups, could apply for small grants with which to purchase key inputs and organize training for themselves and others. With the assistance of ICRISAT's scientists in Kenya, the Ivuso women submitted a proposal for funding to buy a small diesel-powered mill and a dehuller, together with such accessories as baking utensils and aprons.

Multiplying value

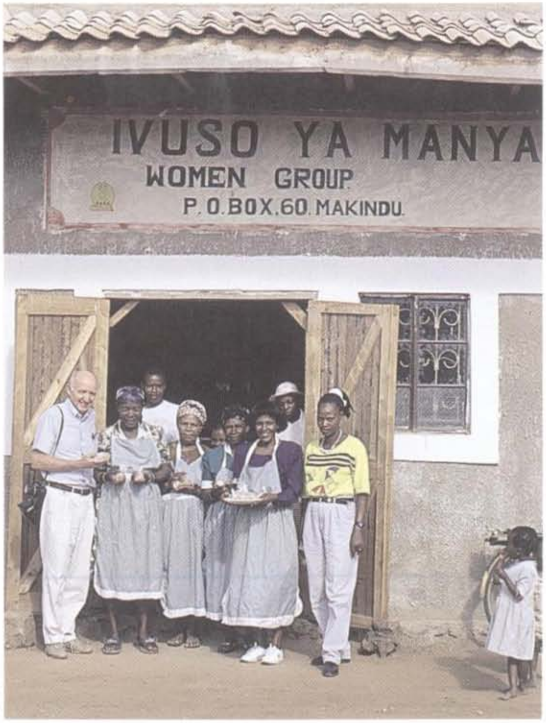
As soon as USAID had approved the proposal, a manufacturer was identified and the machines were ordered. Four of the women went to Nairobi for training from the supplier in their use. In August 1996, Makindu's village chief attended a ceremony to inaugurate the newly installed equipment.

According to Diana's records, sales of biscuits and cakes have since risen steadily. The women have also cornered a large share of the local market for milling and dehulling, having gained a reputation for providing a better product at a lower price.

Diana doesn't plan to stop there. Next on her shopping list are a couple of bicycles with wooden boxes mounted at the back, so that the women can peddle the group's wares at village markets in the surrounding countryside. And her plans for the longer term are even more ambitious. Beyond the shop rise the half-built walls of a larger building, also made from the group's bricks. When finished, this will provide accommodation for visiting groups of farmers. The idea is to host seminars and offer training, turning Ivuso into a center of knowledge for the region.

"Other groups are already coming to learn from us", she says. "At the moment we have 40 farmers who are being trained in pigeonpea production. They are studying everything from sowing to harvesting and processing."

Ivuso is the Kiswahili for "spirit of cooperation". The women infused with this spirit are not just adding value to the new drought-tolerant crops they grow on their farms. By sharing their knowledge with others, they are multiplying it.



S Chater

The Ivuso ya Manyatta Women's Group, outside their bakery.

Leading the community

Josephine Muli: not a telephone farmer.

"I'm not a telephone farmer", says Josephine Muli. What she means is that, unlike the new breed of city-dwelling landowner who visits his farm only at weekends, she and her husband live on their land and work it full-time themselves.

Behind the witty epithet lies a serious point. Besides being a farmer Josephine is an acute business woman who is showing others that they do not have to escape from the rural environment to find their way out of poverty. As chairperson of the district association of women's groups, she is also a leading light in the community. It is by being "one of us", not a returnee clutching a paper qualification from some far-off university, that she commands the respect of local people.

In 1995, staff at the Kiboko research station gave Josephine 4 kg of ICPL 87091, a short-duration pigeonpea variety developed by ICRISAT and KARI that is proving popular with women farmers for both grain and fresh peas. She multiplied the seed and obtained 150 kg, which she sold in lots of 1 kg to neighboring farmers. This year about 2 ha of her farm is devoted to seed multiplication.

But demand for seed still far outruns supply, so Josephine has enlisted the support of the district's 160 women's groups to speed up multiplication. Each group has appointed a member to multiply seed, which at harvest will be divided among all the other members.

Mrs Muli disseminates knowledge as well as seeds. She organizes her own courses in seed multiplication and the production of short-duration pigeonpea. She also serves as a resource person on similar courses given by NGOs.

In 1996, in recognition of her potential contribution to technology transfer, Josephine was invited to attend a course at ICRISAT Asia Center on pigeonpea processing and utilization (see box). On the course, she learnt how to make *dhal* Indian-style, using a simple stone grinder called a *chakki*.

On return to Kenya, Josephine began sharing the benefits of her new knowledge by organizing more courses and seminars through the women's groups. Now she is eagerly awaiting the arrival of a cargo of *chakkis*, on their way by ship from India. ICRISAT has ordered 20 each for small-scale processors in Kenya, Malawi, Uganda and Tanzania. The Institute's scientists are also working with a local NGO to investigate the possibility of local manufacture.

Allies

People like Diana Nzomo and Josephine Muli are important allies in the drive to transfer technology to farmers' fields. Besides their natural flair for business and their leadership talents, two other characteristics make them and their groups especially effective.

The first is the ethic that knowledge and skills, like work or money, are for sharing. This means that training and other inputs have a multiplier effect reaching far beyond the group to which they are originally provided.

The second is that the women are all-rounders, embracing the whole range of food-related activities from buying or saving seeds, through growing and harvesting the crop, to processing and marketing. Their breadth and depth of knowledge qualify them to train and motivate others seeking to emulate them. And having worked so hard to produce a crop, they appreciate the importance of adding value to it through processing and the development of new products.

Training in pigeonpea utilization

Pigeonpea has considerable potential in southern and eastern Africa, both for the domestic market and as an export crop. The grain is mostly consumed whole at present. The key to its expansion is to promote more diverse forms of utilization, especially as *dhal* or split pea. In 1994, with funding from the African Development Bank, ICRISAT mounted a training effort directed towards potential processors in the region.

Three courses were held at ICRISAT Asia Center, the first for food scientists and technologists, the second for rural women interested in small-scale processing, and the third for commercial agro-industrial processors. Manufacturers of processing equipment also attended the third course.

The course for women focused mainly on processing and cooking methods. Participants learnt several preconditioning treatments to enhance dehulling, including soaking, boiling, frying, and roasting. They studied traditional and modern dehulling methods used in India, including the *chakki*. They also tried out more than a dozen recipes and learnt about the nutritional and food quality aspects of pigeonpea.

As a follow-up, ICRISAT and national partners organized in-country courses for women farmers, extension staff, and community development workers in Kenya, Tanzania, Uganda, and Malawi. These courses repeated the syllabus covered in India, using as resource persons some of the participants of the earlier courses.

Has *Helicoverpa* met its match at last?

No single method of controlling the podborer (*Helicoverpa armigera*) has yet given complete and lasting protection against this devastating pest. But a combination of methods, skilfully deployed in an integrated pest management (IPM) approach, could just work.

Seeing for themselves

When Narsa Reddy saw the dead caterpillars hanging from his chickpea crop, he was impressed."This is a product we'd like to see on the market", he said.

The suspended corpses – "like suicides", as one researcher put it – were the characteristic signature of a naturally occurring disease of podborer caused by the nuclear polyhedrosis virus (NPV). This outbreak of the disease, however, owed less to nature than to man. A few days previously, under the guidance of ICRISAT researchers, Reddy had applied a slurry made from infected dead caterpillars to the most densely infested parts of his crop. Slurries of this kind are currently under development at several agricultural universities in India.

Death by hanging: NPV leaves its mark.

Reddy is one of several farmers in his village who are seeing for themselves what this and other IPM methods can do to save their chickpea crop from a pest that has become almost impossible to control by conventional means.

An indestructible pest

Helicoverpa armigera is the most serious cause of damage to chickpea in southern India. During the rainy season, populations build up on other crops, notably cotton. Sown in the postrainy season, when few other crops are available, chickpea is a preferred host for egg-laying moths. The hatched larvae seize with delight on the buds, flowers, and young pods of the growing crop. Attacked just when it is most vulnerable, the crop often fails to recover and yields extremely poorly.

To make matters worse, the podborer has now become resistant to most chemical insecticides. It acquired its resistance on cotton and high-value vegetable crops, where farmers have repeatedly subjected it to spraying over decades.

The search for alternatives

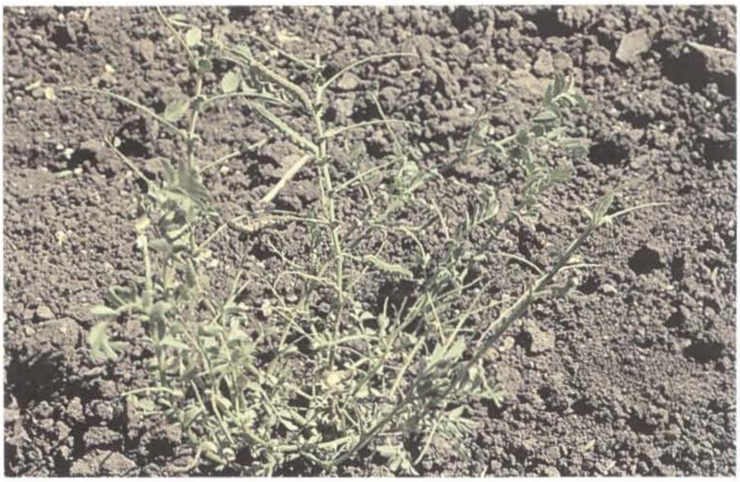
At present, farmers have few alternatives to synthetic insecticides. In India, some use neem-based preparations. But these need frequent applications to be effective, making them labor-intensive and costly. NPV products have shown promise, but few have yet reached the market. Genetic resistance in the host plant, insofar as it exists at all, is associated with low yield.

In 1995, ICRISAT joined forces with the Deccan Development Society (DDS), a non-governmental organization, to launch participatory on-farm research in three villages in southern India's Deccan Plateau. The aim of the research was to explore the range of alternatives available and to improve their effectiveness where possible.

The partners planned a "pincer" attack on the pest, following two approaches: one was "deep green", using no insecticides, and the other "light green", making minimum use of biopesticides or of the best available chemical product when necessary. While ICRISAT conducted the light green research, experiments using the deep green approach were the responsibility of DDS.

ICRISAT scientists had previously studied the effect of different population densities of *Helicoverpa* larvae on grain yields of chickpea. They had found that a density of two larvae per plant constituted the "economic threshold", or in other words the level of infestation at which intervention becomes worthwhile. If farmers could apply an effective insecticide when populations reached this level, they could triple their yields from 700 to 2000 kg ha^{-1}.

Farmers participating in testing the light green approach were asked to leave a quarter of their fields untreated. In the other three-quarters, they applied three separate treatments as soon as the *Helicoverpa* population reached the economic threshold. The treatments were the best commercially available insecticide, a locally available neem-based bio-insecticide, and an NPV slurry available for experimental purposes.



The crop often fails to recover.

In the first season, the NPV product performed poorly. It had to be applied even more frequently than the neem-based product to push infestation levels below the two-larvae limit, and did not raise yields much above the control. Treatment with the neem-based product, in contrast, resulted in yields only slightly lower than those obtained using the best available commercial product, which achieved the best results of all.

For the second season, the scientists switched to a different NPV product. This time the results were much more encouraging: yielding 869 kg ha^{-1}, NPV-treated crops did nearly as well than those treated with the commercial product, which yielded 919 kg ha^{-1}.

Reddy and his fellow farmers were delighted. As well as urging the scientists to convey their opinions on the different products to the suppliers, they asked for training in how to make NPV preparations themselves.

These results suggest that NPV products could form the centerpiece of a more environmentally friendly approach to *Helicoverpa* control. But before that can happen, the many problems associated with their manufacture and distribution will have to be overcome (see box).

Manufacturing and distribution constraints

The quality of the NPV products available in India is highly variable. The most serious problem is contamination with other, less virulent, pathogens during manufacture. Other problems include the products' sensitivity to temperature and ultraviolet rays, both of which reduce shelf-life and the duration of effectiveness on plant surfaces.

The private sector has been slow to enter the market for NPV products, partly because of the difficulty of recovering R&D costs in the case of a product whose origin is a naturally occurring virus. A few companies have recently launched products, but for the most part quality remains poor.

The case for public-sector research is therefore strong. Funded by the Indian Council of Agricultural Research (ICAR), such research is now being undertaken by several agricultural universities in India. Product quality remains variable, but there are signs of progress.

Also conducting research to improve NPV products is the Natural Resources Institute (NRI) of the UK. At its Asia Center ICRISAT has hosted two short courses given by NRI on quality control during manufacture. Participants were drawn from both the public and the private sectors.

The deep green approach being tested by DDS covers a range of options representing a synthesis of indigenous knowledge and the findings of formal research.

One option is to mix low-yielding resistant varieties with high-yielding susceptible ones, an idea that has worked in small-scale plots on the research station. The resistant varieties somehow "protect" the susceptible ones, and overall yields are increased.

Another option is the use of marigolds – those bright orange flowers beloved of India's garland-makers. These are said to attract podborers and could therefore have potential as a trap crop. At present they are grown mostly in home gardens, near vegetable plots. Now the idea is to try them out as a field border round chickpea crops.

A third option, the use of pheromone traps, was originally introduced for experimental purposes, to monitor pest populations. When they saw how well the traps worked, farmers expressed enthusiasm for them. Researchers have their doubts, however, as the traps only catch male moths.

Lastly, bird perches are being used to encourage visits by these natural enemies of insect pests. This is a simple idea originally developed by farmers and now being more widely promoted by scientists.

Outlook

The two-track approach to *Helicoverpa* control being developed by ICRISAT and DDS should lead eventually to a single package that will enable farmers to hit the pest as hard as possible with deep green control methods, while keeping stronger measures in reserve if these methods fail to work.

Farmers seldom take adequate precautions when applying insecticides, IPM reduces the risks they take.

Using this strategy, farmers should, in the long term, be able to reduce their consumption of insecticides and slow down the buildup of resistance in the pest.

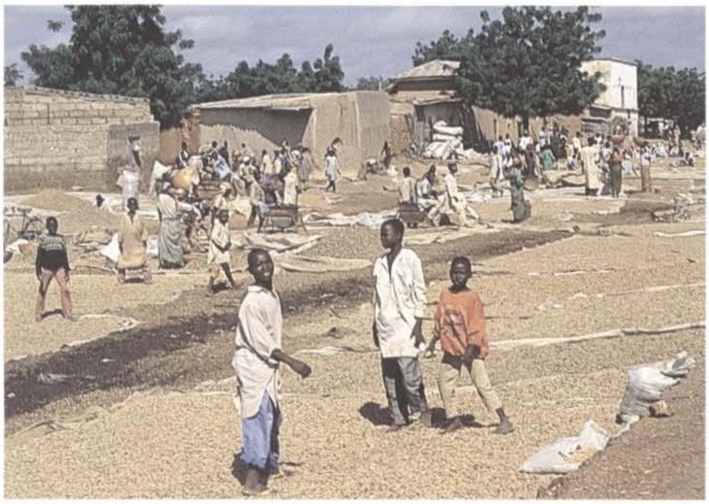
However, farmer participation in technology development is vital if this scenario is to become a reality. Only by seeing for themselves that IPM works will farmers gain sufficient confidence and skill to apply it effectively. The need for a synthesis between formal and informal research in the pursuit of this objective has never been greater.

Rebuilding the pyramids

The area devoted to groundnut in western Africa has fallen to record low levels. The key to recovery is restoring farmers' confidence that they can grow the crop without losing their harvest to a devastating disease.

A lost trade

Kano's "groundnut pyramids" used to be proudly pointed out to visitors. The huge piles of sacks that tapered to a point higher than most of the city's buildings were a symbol of northern Nigeria's abundance in an important cash crop. Strategically placed at the center of regional production and the head of the railway line to Lagos, Kano was once a staging post in a thriving export trade to the markets of Europe.



Suresh Pande

Groundnut trade is well below its former level.

Today the dusty yards where the Groundnut Marketing Board stock-piled farmers' harvests lie almost empty. In Nigeria, as in the other major producer countries of western Africa, groundnut production has never recovered from the disaster that struck in 1975, when an epidemic of rosette disease destroyed nearly three-quarters of a million hectares of the crop and wiped out regional trade worth an estimated US$ 250 million. Combined with aflatoxin contamination, rosette disease is a major reason why buyers turned away from Africa to other, more reliable suppliers.

R A Naidu

Rosette disease: a major cause of groundnut losses in western Africa.

Transmitted by aphids, rosette disease remains a major constraint to groundnut production across western Africa. Yield losses of 10 to 30% are common, but rise to 100% when the


H S Duggal

Poor farmers can't take risks with their crops.

disease reaches epidemic proportions. Many of the farmers who suffered financial ruin in 1975 have since stuck to safer crops such as cowpea, sorghum, and pearl millet.

The search for solutions

Quick to realize the need to restore farmers' confidence, scientists at Nigeria's Institute of Agricultural Research (IAR) began research on rosette disease in 1976. At first their studies focussed mainly on cultural practices. The scientists found that spraying to control aphids could be effective. They also showed that bringing forward sowing dates allowed the crop to mature before aphid populations reached their peak, and that using denser plant stands discouraged infestation, since aphids prefer light airy conditions.

But the smallholder farmers who grow groundnut often face difficulties in adopting such practices. Few can afford pesticides, which are usually unavailable in any case. Most give priority to subsistence crops such as sorghum or pearl millet and have little labor spare to sow groundnut earlier. And almost all use wide plant spacing to offset the risks of drought.

These adoption constraints, coupled with a run of dry years in the early 1980s that led to rising aphid populations, pointed to genetic resistance as potentially a more promising way forward. In 1986, IAR's scientists redirected their efforts towards identifying sources of resistance and incorporating this trait into new, short-duration varieties.

Support for national efforts

ICRISAT joined the search for solutions to the rosette disease problem in 1987, when three scientists began research on groundnut at the Institute's Sahelian Center, in Niger. With a strong national team already at work at IAR, the need was to support rather than duplicate Nigeria's efforts and to spread the benefits of research to other countries in the region.

In 1992, the two institutions launched a collaborative research program to promote the exchange of germplasm and conduct joint trials.

The scientists' first move was to broaden the search for resistance by accessing the germplasm collection held at ICRISAT Asia Center, in Hyderabad, India. This proved a fruitful source of early-maturing resistant lines. However, most of these lines yield poorly and did not catch on with farmers.

A further source of new materials was Malawi, where resistant long-duration varieties were available in addition to short-duration materials earlier imported from India. The long-duration materials yield well in higher-rainfall areas but do poorly when drought strikes at the end of the growing season, as it often does in western Africa.

By crossing the two types of material, scientists have been able to incorporate resistance to rosette disease into a productive short-duration background. Subsequent selection at IAR's Samaru research station has led to the identification of several promising lines.

Besides developing improved breeding materials for Nigeria, IAR has become a source of resistant seed for the region. Six countries have benefitted to date, namely Benin, Burkina Faso, the Central African Republic, Chad, Ghana, and Mali. The materials were disseminated through ICRISAT's regional testing program.

Methods on the move

Behind the rapid advances made by the joint IAR/ICRISAT program lies another import from Malawi, this time a methodology.

Scientists screening for resistance to rosette disease used to have to rely on natural infestation, normally around 10 to 30%. This meant that many of the plants that looked resistant were in fact "escapes" – plants that had simply not caught the disease. The impossibility of distinguishing between the two led to many false hopes, delaying progress considerably.

Suresh Pande

Screening for rosette resistance at the Institute of Agricultural Research, Nigeria.

Research in the 1980s led to a better understanding of the epidemiology of the disease, including its transmission by aphids. With this came the opportunity to develop more efficient screening methods. ICRISAT scientists in Malawi came up with the infector row technique, in which a test row of noninfested plants is flanked on either side by a row of plants infested with aphids that have been mass reared in the laboratory. To ensure that they carry rosette, the aphids are fed on already diseased plants. This technique leads to a 99% success rate in spreading the disease to susceptible plants, with the result that the few cases of true resistance become much easier to detect.

In 1991, IAR's groundnut breeder, Dr Phindile Olorunju, visited Malawi to learn the technique. On her return to Nigeria she put her new knowledge into practice, relieving ICRISAT of the need to be actively involved in the screening exercise at Samaru.

Dr Olorunju is also spreading the technique to other national programs in the region. She spent the first part of the 1994 season training a pathologist and a technician from Burkina Faso, who visited Samaru with ICRISAT support. Now the Burkinabe team are also screening materials independently, at Niangoloko, the country's hot-spot for rosette disease.

When national scientists attending the Third Regional Groundnut Meeting in 1994 heard of these activities they thanked ICRISAT for enabling the region's groundnut scientists to benefit from each other's experiences and skills and asked that the Institute continue its support.

B R Ntare

National researchers share knowledge: Burkina Faso's Dr Phillipe Sankara (right), visited IAR, Nigeria.

Towards recovery

An important research task for the region has been successfully devolved to a strong national research program that is now sharing both its knowledge and its materials with other countries. ICRISAT's experience with IAR shows that research methods can move horizontally between countries, just as germplasm can.

The progress of the past few years has brought Nigeria and its neighbors several steps closer to rebuilding the production of an important cash crop. Kano's pyramids may one day rise again.

Some like it cold

Most people think of sorghum as a low-altitude crop. But in eastern Africa it's grown at a range of altitudes from sea level to over 2000 meters. ICRISAT's Kenya-based sorghum breeder has been sifting the Institute's germplasm collection for suitably adapted lines.

Unique environments

It takes only a few minutes to drive from Kabete to Muguga, but for the purposes of sorghum production the two are worlds apart.

At 1912 m, Kabete, on the outskirts of Nairobi, enjoys a moderate climate with average monthly temperatures seldom dipping below 17°C. Muguga, perched near the top of the Rift Valley escarpment a few miles further north, is only 184 m higher than Kabete, but its climate is markedly cooler. Here temperatures during the growing season frequently fall below 11°C – the critical threshold for seed setting and grain filling in most varieties of sorghum.

S Chater

Sorghum is widely grown in Ethiopia's highlands.

The two contrasting locations illustrate the diversity of the environments so often lumped together as highlands. They also show how important it is to tailor sorghum germplasm to specific ecological niches.

Sorghum is highly vulnerable to cold, which may cramp the crop's growth and development at almost all stages from germination through flowering to seed setting and grain filling. It is also acutely sensitive to small changes in temperature. A fall of as little as 2°C can greatly affect the crop's behavior. And when temperatures dip below 11°C – as they often do during the cropping season above 2000 m – problems of grain production become severe.

As a rule, temperature falls with altitude in the eastern African highlands. But the relation isn't a linear one, the decline tending to accelerate above a certain critical height – around 2000 m in the case of Kenya. And the picture is further complicated by the effects of latitude, season, and rainfall pattern. For instance, the dry highlands of northern Ethiopia and Eritrea experience cooler night temperatures but are hotter by day than the more humid highlands of Uganda and Rwanda, where cloud cover cushions temperature fluctuations. Again, temperatures south of the Equator, in the highlands of Kenya, fall to an annual low during July, in the middle of the growing period, whereas at northern latitudes they do so only in December-January, when the rainy season is over and most crops have been harvested. These subtle differences alter the type of temperature stress to which crops are exposed.

This means not only that sorghum varieties from other parts of the world seldom do well in the eastern African highlands but that, within the highlands themselves, performance can vary greatly from one location to another. As a result the region's scientists cannot rely on technology borrowed from elsewhere but must conduct their own screening experiments at contrasting locations, using materials originating within the region.


S Chater

Poorly adapted lines tiller excessively.

A valuable screening exercise

ICRISAT's research on highland sorghums for eastern Africa began in earnest in 1994, when it became clear that materials selected for lowland environments regularly failed at higher elevations, and that materials selected for other highland environments – notably those of Central America – were poorly adapted. Kenya, with its diverse highland locations, appeared the ideal country in which to conduct a screening exercise for the region.

The first step was to ask the Genetic Resources Division at ICRISAT Asia Center to identify all the accessions in its genebank that came from relevant countries with a significant highland area. The search identified around 900 accessions. These were imported to Kenya, together with a few lines obtained directly from Rwanda.

With his partners at the Kenya Agricultural Research Institute (KARI), ICRISAT's sorghum breeder then conducted a 2-year multilocational screening trial, using Kabete and Muguga as the main highland locations during the first year. These locations were complemented by additional testing at Njoro (2244 m) for a few of the most promising accessions and at Kiboko (960 m) as the lowland site. In the second year, at KARI's initiative, a fourth highland location was added at Lanet (1920 m), together with a second lowland site at Mtwapa, near sea level.

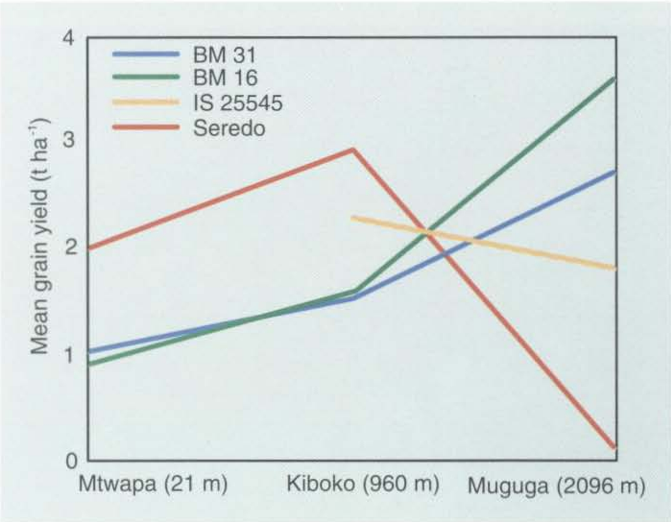


Figure 1. Seredo, a susceptible variety, yielded best at Kiboko but failed altogether at Muguga, where cold-tolerant BM 31 and BM 16 produced their highest yields.

The results showed how complex is the task of matching germplasm to environments in eastern Africa's diverse highlands. Figures 1 and 2 illustrate the performance of susceptible and cold-tolerant sorghum varieties across several locations in Kenya. Generally, lines that did well at lower altitudes performed poorly or failed altogether at higher ones, and vice versa. But there were important exceptions. A handful of lines showed somewhat broader adaptation, performing reasonably well across locations. And some moderately adapted germplasm produced adequate yields at low altitudes and good ones at medium to high ones, but still failed under the more punishing conditions at the very highest locations.

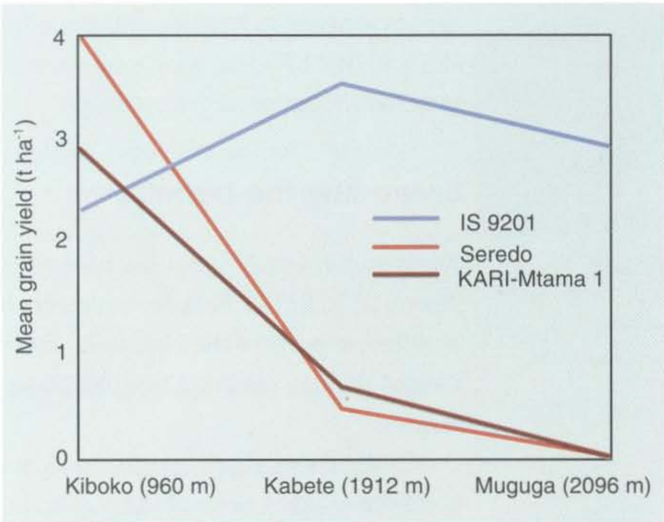


Figure 2. The cold-tolerant line IS 9201 has a fairly stable performance across environments.

A few lines proved highly tolerant to cold temperatures, producing 100% seed set and high yields at well over 2000 m. These "elite" materials outperformed Kenya's existing improved cold-tolerant variety, E1291, by up to 36% at a range of high altitudes.


S Chater
ICRISAT's Kenya-based sorghum breeder at work.

Broadening the genetic base

The genetic base of East African highland material is relatively narrow, exposing it to attack by pests and diseases. In addition, few highland lines have the large, white grains commonly preferred by consumers for food production. ICRISAT and KARI scientists have responded by crossing a few cold-tolerant lines with an improved lowland variety. They are now studying the performance of the progeny.

As might be expected, many of the crosses perform well at Kabete but cannot set seed at Muguga. But three lines – IESV 91068 LT, IESV 91067 LT, and IESV 91069 LT – had good seed set and produced high yields at both locations. This material should prove exceptionally valuable in national breeding programs.

Spreading the benefits

As its host country, Kenya has been the first to benefit from the screening exercise. About 12 ICRISAT lines have recently been entered into national performance trials in different parts of the highlands. Two of these are already being tested on-farm. One of them, a selection from Rwandan material, is proving highly popular with farmers.

ICRISAT's sorghum breeder has lost no time in spreading the results of research in Kenya to other parts of the region. In 1996, he sent nurseries of cold-tolerant lines to Eritrea, Ethiopia, Rwanda, and Uganda. Several of these countries should be in a position to release new varieties within the next 3 to 4 years.

Lost and found: a valuable trait in pearl millet

For years, ICRISAT's breeders weren't sure whether yellow pearl millet really existed. Now, thanks to the Institute's germplasm collection, they know it does. And they're discovering how useful it might be.

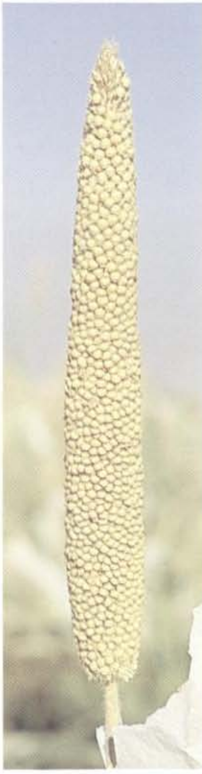
Nutritional implications

The seeds of cereals have three main parts: the protective seed coat, the embryo, containing root and shoot growing points, and the endosperm or inner part, that provides a store of nutrients for early seedling growth. Consisting of a hard outer layer and an inner floury core, the endosperm is the main source of starch and protein – and hence of human food.

The outer layer of the endosperm in pearl millet is normally grey, cream, or white. However, pearl millet is closely related to maize and sorghum, and since yellow-grained varieties are known in both these crops it seemed likely they would exist in pearl millet too.

The breeders' search for yellow endosperms was not driven by idle curiosity. Yellow maize contains beta-carotene, the precursor of vitamin A. The diets of poor people in developing countries are often deficient in vitamin A, leading to malnutrition, disease and, in severe cases, blindness. Pearl millet is grown in many areas where other sources of vitamin A, such as fresh vegetables, are scarce for much of the year. If yellow pearl millet also contained beta-carotene, it might be especially useful in overcoming this deficiency.

But this could not be guaranteed. Yellow sorghum, when it was found in the 1950s, proved a disappointment to breeders, containing not beta-carotene but pigments known as xanthophylls that have no nutritional value.


C T Hash

Yellow pearl millet could help prevent malnutrition.

Now you see it...

Yellow endosperm is a trait that has been playing hide-and-seek with breeders for decades.

A search of the world literature suggested that the trait was extremely rare. Only one case had ever been reported – from the *dauro* variety, a traditional landrace whose distribution is limited to the Jos Plateau of central Nigeria.

...now you don't

The Nigerian report dated back to the 1960s. If yellow-grained accessions of *dauro* had ever been collected at that time, they had apparently since disappeared from world genebanks. The largest active collection of pearl millet in the USA, held at Tifton, Georgia, contained no record of yellow endosperms. Nor was anyone in ICRISAT's Genetic Resources Division able to trace the trait. The breeders began to wonder whether it existed at all.

Complicating the search was the fact that the trait is only occasionally visible. Seed coats in pearl millet are often whitish or pigmented, masking what lies beneath. Only when they are transparent does the color of the outer layer of the endosperm shine through. And this layer must be sufficiently thick for the color to show.

Caught at last

Each year, a proportion of the accessions held in ICRISAT's genebank is grown out in the field to ensure the continuing viability of the seed, and to explore its characteristics. The Institute's pearl millet breeders are invited to tour the plots while the plants are growing, in the hope of spotting new and potentially useful traits.

It was during the 1992 tour that flashes of yellow in a couple of plots caught the eye of one of the breeders. The plots contained accessions from Burkina Faso. Most of the plants of these accessions bore panicles with the usual blue-grey grains. But a few had speckled heads including a small proportion of yellow seeds. Cutting open these seeds revealed that it was indeed their endosperms, not their seed coats, that were yellow.

The next step was to fix the trait by self-pollinating the plants and selecting those in which it was most strongly expressed. After two generations, the scientists had plants with uniformly yellow grain. From these they were able to harvest enough grain to carry out a laboratory analysis for beta-carotene content.

The results of the analysis fulfilled the scientists' hopes. The yellow-grained selections from the Burkina Faso accessions had nutritionally significant contents of beta-carotene, whereas grain from grey- and white-grained varieties had none.

The scientists immediately asked the Genetic Resources Division to grow out all similar accessions in the collection. This exercise has so far revealed another 30 accessions with yellow endosperm. These are from several western African countries, including Sierra Leone and Nigeria in addition to Burkina Faso.

In a related evaluation, breeders examined over 100 Nigerian accessions of the *dauro* landrace. Of these, only one was found to contain genes for yellow grains. As they studied yellow-grained plants of this accession, the scientists realized why the trait had remained a closely guarded secret. The yellow color is visible only for a short period during the middle stages of grain formation, while the seed coat is still transparent. As the seed approaches maturity, its coat turns brown. To spot the trait, observers must watch the crop at just the right time.

All the yellow-grained accessions so far identified are photoperiod-sensitive long-duration varieties of the kind that, outside western Africa, has hitherto been little used in most pearl millet breeding programs – another reason why the trait has remained hidden for so long.

The accessions showed significant variability in agronomic traits. Whereas those from Burkina Faso had weak stalks and poor grain yields, the *dauro* variety had relatively long heads and large grains, making it the best of the bunch from a plant breeder's viewpoint. The scientists now intend to use this and other varieties for crossbreeding to study the inheritance of the trait and, if possible, transfer it into a higher-yielding background.

If their efforts are successful, this hitherto rare trait could make a valuable contribution to the eradication of malnutrition in the semi-arid tropics.

Striga control: a new way forward

A fungus better known as the cause of wilt disease in grain crops is raising hopes of a new way forward in the struggle against *Striga*.

A formidable enemy

Ablaze with purple, the crop fields wear the flowers of *Striga* like an identity badge. Nothing more clearly announces the poverty and hardship of rural life in Africa's drylands than the presence of this parasitic weed, which is associated with declining soil fertility in drought-prone areas where cereals are monocropped without the use of fertilizers.

K V Ramaiah

The scourge of purple

Striga is probably the single most serious biotic constraint to crop production in sub-Saharan Africa, affecting an estimated 44 million hectares of cropland and causing yield losses worth up to US$ 7 billion a year. Of its several species, the three most serious are *Striga hermonthica*, *S. asiatica*, and *S. gesnerioides*. The first two attack cereals, including pearl millet and sorghum, while the third affects legumes such as cowpea.

Hard to detect initially, *Striga* is equally hard to get rid of once it has become established. After germination, *Striga* seeds attach themselves to the roots of their host cereal or legume crop, stealing its nutrients. Much of the damage to crops is thus done underground, before the weed emerges. On flowering, each *Striga* plant produces up to 500 000 minute seeds that can remain viable in the soil for up to 15 years. With few options for control, many farmers are forced to abandon their fields when infestation becomes so severe as to render futile any attempt to grow a crop.

Conventional approaches to control have brought limited success, especially when used in isolation. Chemicals can be effective, but are frequently too expensive for resource-poor farmers. Host plant resistance is a more economical option, but breeding progress thus far is limited. Weeding by hand is feasible only in lightly to moderately infested fields. *Striga* flourishes when soil fertility is poor, but resource-poor farmers often either cannot afford or cannot obtain inputs of commercial fertilizers, and many face difficulties in adopting other fertility-restoring practices.

The best hope for control lies in an integrated approach combining several control methods. Recent research suggests that biocontrol could be an important component of such an approach.

E M McGaw

Striga hermonthica: *many farmers abandon their fields when infestation becomes severe.*

The potential of biocontrol

Like all plants, *Striga* has natural enemies – predators or parasites such as insect pests or fungal pathogens that feed and multiply on it. In 1989, a Sudanese PhD student working with the University of Hohenheim began looking for natural enemies in the Blue Nile region of his home country. Sudan is believed to be the center of origin of *Striga* and had therefore been identified as a good place to start the search.

The scientist discovered that a microscopic fungus, *Fusarium nygamai,* caused wilt disease in *Striga,* often with fatal results. Isolated and grown in culture, the fungus was shown to be highly effective in killing *Striga* seeds. However, it was also found to produce Fuminosin 1, a mycotoxin hazardous to animals and human beings.

Fusarium nygamai is only one of many species in the *Fusarium* genus, each specific to a fairly narrow range of hosts. In the mid-1990s, ICRISAT joined Germany's University of Hohenheim and the Justus-Liebig University of Giessen in a new project to explore the potential of a wider range of *Fusarium* or other fungal species to control *Striga* in western Africa. The project, which is based at the ICRISAT Sahelian Center, near Niamey, Niger, conducts research across the region's sorghum and pearl millet belt.

Surveys in Burkina Faso, Mali, and Niger revealed 11 genera of fungi attacking *Striga.* The commonest was *Fusarium,* which was isolated from more than 90% of diseased plants. Of the four species of *Fusarium* found, *F. oxysporum* was at once the most prevalent and the most virulent. Tested under controlled greenhouse conditions in Germany, isolates from Ghana gave 100% control of *Striga.*

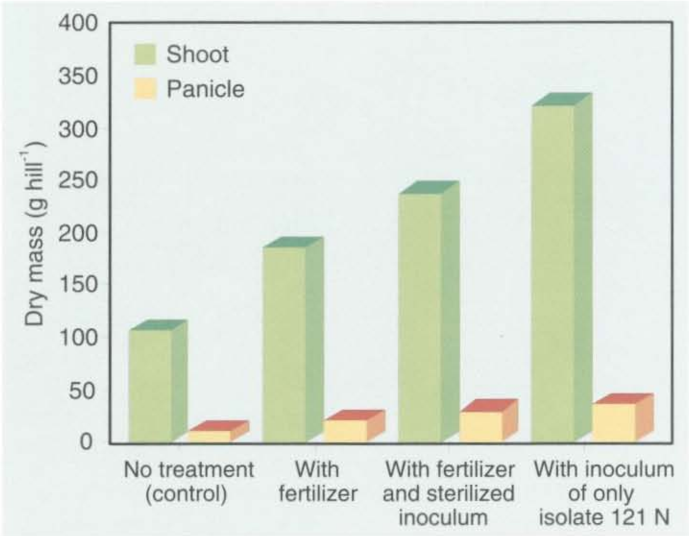


Figure 1. Effect of Fusarium oxysporum *(isolate 121N) on sorghum shoot and dry panicle mass.*

Next came the crucial step of testing the isolates in the less predictable environment of farmers' fields. Fungi need moderate temperatures (25–30°C) and soil moisture to give optimal control under field conditions. In a year of poor rainfall, the scientists achieved good results at five locations in three countries. These trials also allowed the most effective isolates to be identified. In one trial on sorghum, an isolate known as 121N achieved over 90% control, leading to a threefold increase in sorghum biomass (Fig. 1).

There are several reasons why *F. oxysporum* shows such promise as a biocontrol agent. First, it attacks *Striga* at all stages of the plant's development, including ungerminated seeds. Reducing the seed bank in the soil is crucial for long-term control. Research in Germany has shown how the hyphae of *F. oxysporum* penetrate the seed coat to invade the cells within, which rapidly decompose. As a result, the seed dies.

Second, the strains of *Fusarium oxysporum* tested so far appear to have just the right degree of host specificity. While attacking both the major species of *Striga* (*S. hermonthica* and *S. gesnerioides*), they do not cause wilt in sorghum, pearl millet, or other important crops grown in western Africa.

Third, the presence of *F. oxysporum* may even enhance crop growth. Sorghum plants associated with *F. oxysporum* grow taller than those which are not. The mechanism at work here remains unclear: research at ISC suggests that infected plants produce more phyto-hormones, possibly as a defence against the fungus; meanwhile, in a separate experiment in Germany, isolates of *F. oxysporum* have been found to produce the same hormones, which are thought to be translocated to the plant's roots through water.

Fourth, because they are soilborne organisms, *Fusarium* species are better protected against environmental extremes than are other bioherbicides, which are applied above-ground. This is especially advantageous in the semi-arid tropics, with their high temperatures and scanty rainfall.

Technology exchange

The challenge now is how to move these results to farmers' fields. One possibility is to hand the findings over to chemical companies – with the proviso that the technology should not be patented. The companies could produce the fungus in a granulated form mixed with nutrients for use as a soil additive. But this product might be too expensive for resource-poor farmers.

Another alternative is for farmers to produce inoculum on their own farms. ICRISAT and its national research partners are experimenting with the use of straw and compost, both of which can be incorporated into the soil by farmers when they sow their crops.

In the straw method, the straw of millet or sorghum is chopped and placed on moist ground under a plastic sheet, where it is left to heat under the sun for 25 days to kill off other organisms. Wrapped in the sheet, the straw is then taken inside to cool to room temperature before isolates of the fungus are introduced. After 4 or 5 days, the inoculum is ready for incorporation into the soil, shortly before crops are sown.

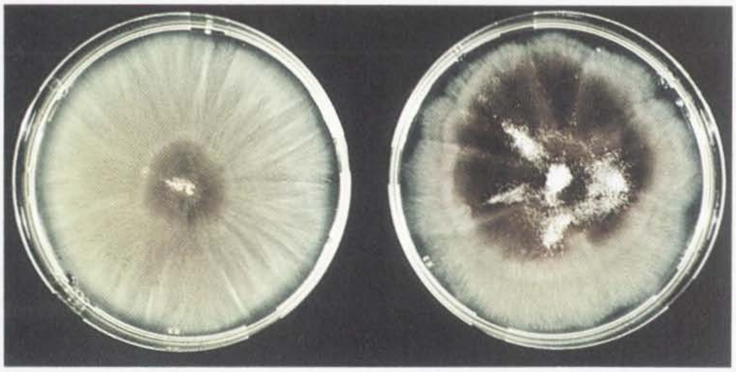
S Chater

Compost makes a good inoculum.

The compost method requires the digging of a compost pit, which is then filled with crop residues, animal dung, and water. These ingredients are mixed and turned at regular intervals for 3 months, after which the mixture is sterilized and inoculum is added.

Of the two, the compost method is the more complex and labor-intensive. But compost making is traditional in some parts of western Africa, so in these areas at least the chances of adoption by farmers are good. This method has the added advantage of being both prevention and cure, since as well as killing existing *Striga* populations it increases soil fertility, reducing the probability of future re-infestation.

The screening process



A A Abbasher

To test the effectiveness of different *Fusarium* species and strains, the scientists first collect foliage, stems, or seeds of diseased *Striga* plants. The plant parts are chopped in the laboratory and placed on a medium used for culturing fungi and bacteria, known as potato dextrose agar (PDA). Once the fungus has grown, the scientists isolate pure cultures and identify them, preserving those of the species and strains they wish to investigate.

The next stage is to create an inoculum – a portion of infected material such as straw that can spread infection when introduced to the soil. Different strains and inocula are tested under controlled conditions in the greenhouse or on the research station. The tests reveal the strain's pathogenicity, or in other words its effectiveness in causing disease, and its host specificity – the range of *Striga* or other plants controlled.

Promising strains and inocula are then tested in researcher-managed experiments on farmers' fields, where a further range of variables can be explored. These include the best time at which to incorporate inoculum, the amount of labor required, and the stability of strains across different environments.

Spot-on chemical intervention, down on the farm

Knowing when to spray against leaf spot diseases of groundnut is now easy, thanks to a new low-cost instrument developed and tested by ICRISAT and its partners.

Unpredictable diseases

K D R Wadia

Leaf spot diseases can devastate the groundnut crop.

Early and late leaf spot diseases occur wherever groundnut is grown under rainfed conditions, but their severity is difficult to predict. In dry years or places they do not usually cause losses serious enough to warrant control. When the season is wet, the fungi that cause the diseases can – but don't always – multiply rapidly and invade the leaves just as the crop approaches flowering. If this happens the leaves become covered with black spots and fall to the ground, with the result that plant growth is arrested and yields are sharply reduced.

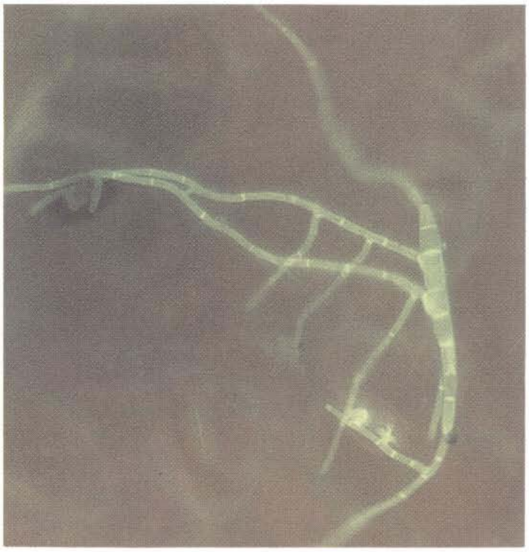
Fungicides to control leaf spot diseases are available in most Asian countries. Research in southern India has shown that farmers can achieve yield increases of 50 to 100% by using them. But spraying isn't always necessary, and should in any case be kept to a minimum on health and environmental grounds. In addition, many farmers are still unfamiliar with fungicides.

ICRISAT and national partners in India have now devised a range of technology options that will help farmers decide when and when not to spray. The system, known as the weather-based advisory scheme, was developed through research that spanned the continuum from strategic to adaptive, providing a good example of how studies that begin in the laboratory can lead to real benefits for farmers.

Understanding the problem

The first step was to gain a better understanding of the conditions determining the development of leaf spot diseases in the lowland semi-arid tropics. Laboratory research at ICRISAT showed that the most important variable in these environments was not rainfall or temperature, but the cumulative period for which the crops' leaves remained wet.

The pathogens causing leaf spots develop only slowly. When spores germinate on the leaves of the groundnut plant, they send out a tube that grows along the leaf surface. The tubes branch to form a network and eventually penetrate the leaf through its stomatal pores – the microscopic holes through which water evaporates and gases are exchanged.


K D R Wadia

Which way to turn? Alternating dry and wet periods provide vital clues to spores seeking stomata on a leaf surface.

The scientists found that penetration takes place only while the leaf is wet, yet is greatly reduced if the leaf is continually wet. Dry periods are vital to promote branching of the tube and growth towards a stomatal pore. The probable reason is that, as the sun dries the leaf, a gradient of humidity is created around the pore, which continues to emit water vapor. The gradient "tells" the tube where to branch and which way the branches should head to find moisture.

The critical role of dry periods explained why leaf spot diseases become severe in some years but not in others. Clearly, leaf wetness would be an important element in developing appropriate control strategies.

Technology development

Despite the importance of leaf wetness, infection won't take place at all unless germinating spores are present in the first place. This necessitated the development of an additional criterion in deciding whether or not to spray – disease incidence. ICRISAT's scientists developed a method in which leaves on young groundnut plants are assessed for the presence or absence of black spots. They found that spraying becomes worthwhile when more than 10% of leaves are infected.

In partnership with the Central Research Institute for Dryland Agriculture (CRIDA) and the Acharya N G Ranga Agricultural University (ANGRAU), ICRISAT scientists tested disease incidence and leaf wetness as criteria for predicting crop losses and defining the point at which farmers should intervene. They showed that, when combined, the two criteria were effective across a range of locations with different average rainfalls.

But to carry out their tests on leaf wetness the scientists had used sophisticated instruments imported from developed countries and suitable for use only on research stations. The challenge now was how to adapt this technology so that farmers would be able to measure this criterion cheaply and accurately in their own fields.

ICRISAT scientists came up with the leaf wetness counter, a new low-cost instrument made from locally available materials. A sensor, consisting of a plastic electronic circuit board shaped like a leaf, is mounted in the crop and wired to a simple counter housed in a metal shelter. The counter, which can be read through a small window, notches up the score every 6 minutes while the sensor is wet, but stops as soon as it is dry. The device works exactly like a stop-watch, with the exception that it does not re-set.

At around US$ 60, ICRISAT's leaf wetness counter is about a fiftieth of the price of equivalent instruments used in developed countries. It also represents a technical advance over some existing models: instead of measuring rainfall per se, it responds to rainfall distribution and the presence of dew, and is therefore a more accurate predictor of leaf spot infection.

D R Butler

A leaf-shaped circuit board detects moisture.

On-farm testing

Encouraged by this breakthrough, the researchers decided to test the system on farmers' fields without further delay. A few prototype instruments were manufactured. The Mysore Resettlement and Development Agency (MYRADA) and Agriculture Man Ecology (AME), two non-governmental organizations active in rural development in southern Andhra Pradesh, were brought in as additional partners, and four villages were identified in which to contact farmers who might like to participate.

In preliminary meetings, the scientists introduced the system to the farmers and asked whether they were interested in testing it. Those willing to participate were trained to conduct the disease assessment exercise. The scientists explained that, when the farmers found infection levels of over 10%, they should check the leaf wetness counter. If the counter showed a score of 460 in a 7-day period, they should spray immediately. But scores below 460 would indicate that spraying was not yet

The counter gives the cue for spraying.

necessary. Farmers were asked to spray only half their groundnut plots not more than three times during the season, and to draw their own conclusions at the end of the experiment.

Six volunteer farmers in each village shared a leaf wetness counter and were provided with free fungicides. The scientists visited the farmers at regular intervals to make sure they were using the counter and assessing disease incidence correctly. The counter caused no problems, but farmers had some difficulty with disease incidence.

Outcome

Results in each village varied, but on average the farmers achieved a yield increase on the sprayed halves of their plots of 25% for pods and around 35-40% for haulms. Assuming fungicide costs of around US$ 15 for two applications, gains of this magnitude should bring farmers a profit of around US$ 70 for the pods alone.

The farmers hailed the experiment as a great success. All said that they would not hesitate to buy fungicides the next season and that they would continue using the counter. And they felt they had learned enough about assessing the disease to use this criterion successfully next time.

Minor technical problems such as flat batteries showed that a more robust model of the instrument is desirable. This will push the cost up slightly, but the instrument should still be affordable if farmers club together to buy it.

The most encouraging outcome of all was farmers' willingness to adopt more subtle control practices than the blanket spraying of a cocktail of chemicals commonly used elsewhere. Despite their unfamiliarity with fungicides, these farmers seemed well aware of the cash and other costs of spraying, and did not wish to spray unless they had to.

Malawi backs a winner

Groundnut CG 7 was the classic case of a new technology getting stuck on the research station shelf – until Malawi's national research team got together with non-governmental organizations (NGOs) and ICRISAT in a bid to relaunch the variety.

Snack or seed?

Groundnuts, as everyone knows, are very "more-ish". Hungry farming families must constantly resist the temptation to nibble away at their seed stocks if they are to have enough to sow at the start of the next cropping season.

That's just one of the seed supply problems facing the Welemans, a family living a few miles down the road from the Chitedze Research Station, on the central Malawian plateau.

The first farmer in her area to test CG 7, Dorothy Weleman has been growing the variety for the past 3 years. But the amount of land she can devote to the crop is tiny – less than 0.25 ha. She says it used to be more – and would be still if only she could obtain more seed. Hers is a typical predicament: a survey showed that around 70% of farmers now have areas this small and that seed shortages are the major problem they face.

Besides eating groundnuts whole, as a snack, Mrs Weleman and her family grind the nuts to make an oily flour. The flour is a vital flavoring and thickening ingredient in *ndiwo*, the sauce made from rehydrated green vegetables that accompanies *nsima*, a thick porridge made from maize flour. The two add up to a popular national dish that is part of the staple diet.

S Chater

The Welemans at home: groundnuts are an important part of the diet, but seed is scarce.

Barely able to meet their subsistence needs and constantly short of seed, the Welemans, not surprisingly, have no surplus of groundnut for sale. Again, they are not alone in this: the slump in production in recent years has led to the disappearance of groundnut from urban markets and the near total loss of Malawi's once lucrative export trade.

Dorothy's situation nevertheless has one redeeming feature. Although she has had to reduce the area sown to groundnut, her yields have increased. "Using CG 7, I get the same harvest from a quarter of a hectare as I would from half a hectare of traditional varieties", she says. The land saved allows the family to grow more maize and tobacco, both of which have, until recently, been more profitable crops.

P Subrahmanyam

Looking for a winner – at ICRISAT's research facility in Malawi.

The technology

CG 7 came into being when scientists at ICRISAT Asia Center crossed a productive virginia variety from the USA with a selection from an Indian landrace adapted to drought. The resulting line, known as ICGMS 42, was sent to Malawi in 1982 and included in regional trials the following year.

Malawi's national groundnut scientists were quick to recognize the new line for what it was – a high yielder with seeds of uniform size and good keeping quality, suitable for confectionery use and with a potential for export. In 1985 they entered it into national yield trials and began testing it at a range of locations across the country.

The results were encouraging. Yields on-station were 71% higher than those of the most widely grown existing improved variety, Chalimbana, while gains on-farm were up to 117%. An even bigger big plus point was CG 7's stability – its ability to produce well across locations and years. Yields held up reasonably well even in 1992/93, a year of severe drought.

After 5 years of on-station and 2 years of on-farm testing, Malawi's National Release Committee gave the new variety its blessing in September 1990. But that, unfortunately, was where matters stopped. Owing to the lack of seed multiplication and dissemination, adoption by farmers was virtually nil.

The seed problem

Part of the explanation lies in the inherent characteristics of groundnut seed. It's bulky and has to be sown densely if the emerging seedlings are not to be choked by weeds or hit by rosette disease. As a result farmers need around 70–80 kg of seed per hectare, compared with only 5 kg for such other crops as sorghum or pearl millet. The seed also has a low multiplication ratio (about 1:20), so seed stocks accumulate only slowly.

These characteristics mean that seed is expensive for farmers at the best of times. But shortly after CG 7 was released, events conspired to exacerbate the problem.

In the late 1980s, Malawi's once efficient seed production program fell into decline as exports collapsed and the country's economy was liberalized. High production costs and unpredictable demand discouraged commercial seed companies from filling the vacuum left by Government. As a result there were no external sources of seeds to which small-scale farmers could turn.

Then drought struck. In the run of exceptionally dry years in the early 1990s, farmers either lost, or were forced to eat, what little seed they still retained.

National program initiatives

"It all began", says Alan Chiyembekeza, head of Malawi's national groundnut research team, "when we did a survey with ICRISAT during the 1992/93 season. Farmers everywhere reported lack of seed as their biggest problem in growing groundnut. No-one had even heard of CG 7, let alone been able to sow any of it."

Chiyembekeza and his colleagues realized that the investment in developing the new variety would be wasted unless they did something. His first step was to talk to the extension service about a field day for women farmers, who had not been targeted by extension efforts. Around 300 women from some of the country's main groundnut growing areas attended the day, organized by the Southern African Development Community (SADC) and ICRISAT, and held at Chitedze Research Station in March 1993. "When they heard about the yields that could be achieved

Seed multiplication: key to rapid adoption.

with CG 7, they were keen to try it out", Chiyembekeza recalls. "That meant we had to produce some seed for them".

By July, all the women had been supplied with just 1 kg of seed. At the end of the growing season, this amount was collected back from them, and used to supply other farmers the following year.

The success of this small scheme encouraged Chiyembekeza and SADC/ICRISAT to organize seed multiplication on a larger scale in order to produce seed for the benefit of NGOs and other interested parties. This happened during the 1992/93 season.

NGO efforts

"When we first started", says Edson Musopole, "we had no seed. But ICRISAT and the national research team came to our rescue." Musopole is the coordinator of seed and environmental projects at Action Aid. His words epitomize the new partnership between research institutions and NGOs that is transforming the prospects for technology dissemination in Malawi.

Edson first learned about CG 7 when he attended a field day at the Chitedze Research Station. "That gave me confidence in the technology, a belief that it would appeal to farmers", he says. "When I saw that the seed companies weren't interested and that no one was multiplying the variety, I decided to get involved". He included CG 7 in a large-scale seed dissemination project covering four administrative divisions where food security is poor.

Edson's confidence has been borne out by events. In its first year, his project distributed around 500 kg of unshelled CG 7 seed to four village groups. In 1996/97, around 8 tonnes will be distributed to nearly 100 groups. "Almost every group of farmers is asking for CG 7", he says.

The project aims to ensure that seed production becomes self-sustaining at village level. To obtain seed, each group of farmers must first open a bank account. Group members are provided with seed on credit at the start of the season, but must repay in cash after they have harvested. The cash goes into a revolving fund held at the bank that can be used only to purchase more seed.

Repayment rates were poor at the start of the project but are now improving, according to Edson. "In the first season, farmers held on to their seed to supply themselves and satisfy family food requirements, so they sold less than we had expected. But sales are slowly picking up as seed stocks rebuild".

It's a pattern that will be repeated across the country, as the efforts of the growing number of NGOs involved in disseminating CG 7 start to take effect.

Nutritional implications

When the NGOs first began coming to Chiyembekeza for seed, at the height of the drought in 1992/93, he had little to give them. In 1995/96, with funding from the United Nations Children's Fund (UNICEF) and support from ICRISAT, he was able to supply 14 tonnes of CG 7, multiplied at the Chitala Research Station. Recipients of the seed included Concern Universal, Action Aid, the International Eye Foundation and the Church of Central Africa (Presbyterian), in addition to two government departments.

Behind the decision to commit UNICEF funds was Abigail Dzimadzi, who heads a US$ 850 000 project that tackles one of Malawi's most pressing rural problems – vitamin A deficiency.

Severe vitamin A deficiency causes damage to the eyes and can lead to blindness. But far more widespread and dangerous are the subclinical symptoms of deficiency, which include diarrhoea and a wasting condition. These kill many children each year, and also lay them wide open to other potentially fatal diseases such as measles.

A healthy diet, that includes indigenous fruits and vegetables can help counter vitamin A deficiency in children.

Several foods eaten in Malawi contain vitamin A, including mangoes, carrots, and indigenous vegetables. A campaign to encourage people to grow and eat these foods is central to the UNICEF project.

But deficiency is also strongly associated with diets that are low in fat, which the body needs in order to absorb vitamin A. "If your oil intake is low, it doesn't matter how many vegetables you eat", says Dr Dzimadzi, "you'll still fall ill".

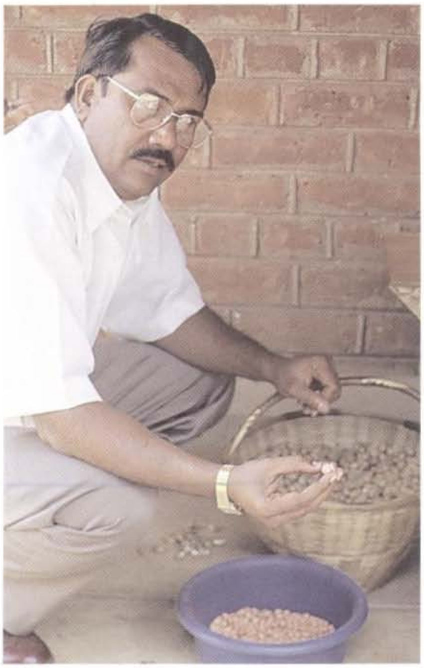
When plentiful, groundnuts are the cheapest source of oil in the Malawian diet. The recent slump in production is therefore a serious threat to the health and survival of the nation's disadvantaged children. UNICEF's support for the dissemination of CG 7 is vital to overcoming the problem.

The European Union initiative

A new project, funded by the European Union, was launched on national radio, which broadcast an advertisement for seed producers. In a response described by Chiyembekeza as "amazing", over 500 people wrote in to apply. A second advertizement was broadcast, asking respondents to attend one of three meetings held at different locations in the country's southern, central and northern regions. "We had a wonderful turnout", says Chiyembekeza, "with over 100 people coming to each location". At the meetings, the project was explained to the farmers, who were told that they would be given seeds and advice, but no cash advances. At the end of the season they would have to pay back an amount of seed equal to what they had received, but would be free to sell the rest.

Next, the national program and the extension service organized training courses in seed production at each location. Then the farmers went away to put into practice what they had learnt. With the project still in its first year, Chiyembekeza cannot yet boast success. But he is confident. "My spies tell me the farmers are managing their crop well", he says.

Chiyembekeza has demonstrated that smallholder seed production schemes have the potential to alleviate Malawi's seed supply problem. The schemes are inexpensive to operate, enabling a significant multiplier effect to be achieved from the distribution of just a few kilograms of seed. As farmers do not have to buy seed, even the poorest can participate.



S Chater

CG 7 has a lot to offer.

Outlook

The new partnership between NGOs, government organizations, and ICRISAT is proving effective in transferring CG 7 to farmers' fields. The prospects for the adoption have therefore greatly improved.

The conflicting needs of impoverished farm families for both food and seed make it difficult to forecast the speed of future diffusion. Nevertheless, CG 7 is poised to make a valuable contribution to improved nutrition and food security in Malawi. In the longer term it could also play a major part in alleviating poverty and helping the country recapture its lost export market.

Out of sight...

In 1996, ICRISAT's Dr Shashi B Sharma won the "Excellence in Science Award" made to a local professional each year by the Chairman of the Consultative Group on International Agricultural Research (CGIAR). The award cites "outstanding achievements" in research in a hitherto neglected area – nematode parasites of food legumes.

The hidden enemies

Widespread in both the developed and the developing world, plant-parasitic nematodes are microscopic worms that penetrate the roots of growing crops, stealing nutrients vital for plant growth and laying the plant open to attack by other pests and diseases. Four main groups parasitize the mandate crops of the CGIAR centers – the root-knot, cyst, lesion, and reniform nematodes.

Nematodes are stealthy, invisible – and smart. They attack their plant hosts underground, out of sight of scientists and farmers. Even when dug up, most species are so tiny that they cannot be seen by the naked eye. They produce no tell-tale symptoms in the above-ground parts of the crop that immediately point to them as the culprits. And, like many parasites, nematodes take care not to destroy their hosts completely, since that would also spell their own demise. "You don't see a devastated crop, just a field that looks off color, not as productive as it should be", as one researcher put it.

The hidden nature of nematode damage is one reason – perhaps the main one – why so little research has been done on them. The CGIAR centers, which might have been expected to take the lead in tackling this global problem, have few programs or projects specifically devoted to nematodes. And few national research systems have qualified nematologists on their staff.

In the decade since he joined ICRISAT in

Simple diagnostic techniques can speed up screening.

1986, Dr Sharma has succeeded in making the Institute something of a leader in this neglected field. He has built up a small laboratory in which, with the support of three associates, he conducts strategic research in collaboration with other scientists and provides a range of analytical services. He has also conducted a considerable amount of field research in partnership with national institutions. And he has been a prolific writer, authoring 128 publications including 71 journal articles and 9 book chapters. The fruits of his labors are a resurgence of interest in nematodes worldwide, and several important contributions to the global knowledge base.

Easy diagnosis

The first challenge facing researchers on nematodes is how to identify them without resorting to the use of a microscope. Farmers too need simple ways of ascertaining whether or not nematodes are present in their fields. To meet these needs, Sharma and his colleagues developed several new diagnostic tools.

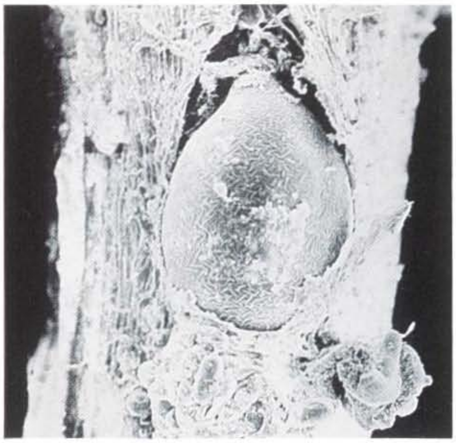
The first, for use by researchers, is a simple chemical stain. Originally intended for detecting reniform nematodes, the stain is also effective for the root-knot group. Both these groups penetrate to the interior of the root, where they are invisible, but lay their eggs in gelatinous sacs that adhere to the roots' surface. To test for their presence, the root systems of pulled plants are dipped in a 0.25% solution of trypan blue dye in water. After two minutes they are removed and the roots are washed with water. If nematodes are present, the dye stains the outer coat of the egg sac a clearly visible dark blue.

Trypan blue stains egg sacs.

Techniques for use by farmers need to be even simpler. Few farmers are as yet familiar with the concept of nematodes, let alone with the tongue-twisting Latin names for them that are bandied about by scientists. If they are to be persuaded to test for nematode infestation in their fields, they must be able to do so quickly and easily. The scientists came up with a simple but effective criterion, that of "dirty roots". Farmers pull up a plant and try to shake the soil from its roots. If the soil sticks, it's a sign that nematodes are probably present.

In the cyst group of nematodes, the females penetrate the root system but swell as they feed, eventually breaking out onto the root surface again. On emergence they are white, but later turn brown. Sharma and his colleagues found that this group can be detected with the naked eye, while plants are at the seedling stage (4–5 weeks old). The white bead-like appearance of the females reminded them of pearls, so they nicknamed this sign "pearly root".

The terms "pearly root" and "dirty root" have since become standard use in the literature on nematodes. They have also proved useful in generating awareness among farmers in integrated pest management (IPM) programs.



A K Murthy

After gorging itself inside the root, the female cyst nematode bursts out onto the surface (magnification: × 100).

New species unearthed

Working with national scientists, Sharma has conducted surveys of nematode infestation in five African and four Asian countries. Several of these surveys broke new ground, revealing the existence of new nematode species or new associations of known species with particular crops.

Among the major discoveries in Africa was that of *Paralongidorus bullatus,* since shown to be one of the most important pathogens affecting millet, groundnut, and sorghum across the Sahel. In Asia, a survey conducted at ICRISAT Asia Center led to the naming of a new genus, *Bilobodera.*

"Pearly root".

Assessing losses

Few studies have been conducted to quantify the damage caused by nematodes. Such studies are vital for defining the infestation levels at which farmers should intervene to control the pests.

Sharma and his colleagues have helped plug the knowledge gap. In pigeonpea, for example, they demonstrated that population densities of more than one nematode per cubic centimeter of soil at sowing can reduce crop biomass and seed yield. Damage becomes severe when infestation exceeds three nematodes per cubic centimeter of soil. In both chickpea and pigeonpea, several types of nematodes were found to suppress the formation of the *Rhizobium* nodules essential for nitrogen fixation.

Sharma has also explored the role of nematodes in relation to other pathogens. He found that resistance to fusarium wilt in chickpea and pigeonpea can break down when root-knot nematodes are present. The nematodes appear to make the fungi that cause wilt more aggressive. This means that, to ensure stable resistance, new cultivars of these crops should be screened in the presence of both pathogens.

Towards environmentally friendly control methods

Research in French-speaking western Africa has shown that chemical control of nematodes is feasible. But Sharma and his colleagues are seeking to develop more environmentally friendly ways of managing these pests.

An important step in that direction was taken with the development of the first ever life table for a plant-parasitic nematode. Much used by entomologists, life tables are a tool for predicting fluctuations in pest populations and identifying weak points in the life-cycle of pests. Compiled for the cyst nematode on pigeonpea, the life table revealed that survival rates were particularly low during the egg stage and the juvenile stage immediately preceding penetration of the plant root. This gives scientists a head start in designing an IPM package.

Genetic resistance is another potentially important component of the package.

When Sharma joined ICRISAT, there were no standard methods for screening for resistance to nematodes in the Institute's mandate crops, and little screening had been done. Sharma conducted painstaking experiments to define appropriate infestation levels and techniques for different crops and nematode species. He then applied his new diagnostic techniques to screen thousands of chickpea, pigeonpea, and groundnut accessions quickly and reliably.

Using the "pearly roots" criterion, Sharma screened over 5000 lines of domesticated pigeonpea for resistance to cyst nematodes. When this exercise failed to turn up useful sources of resistance, he turned his attention to the crop's wild relatives. Here he found high levels of resistance and complete immunity in several accessions of *Cajanus platycarpus* and C. *scarabaeoides*, two vine-like creepers found widely in Asia.

Use of the trypan blue technique to screen for resistance to root-knot nematodes revealed several genotypes of cultivated chickpea that tolerate high egg sac numbers and root damage without showing much damage. Associated with the tolerance was a high uptake of soil calcium. Research is now in progress to establish whether or not this is a resistance mechanism.

In collaboration with Rothamsted Experimental Station in the UK, Sharma has investigated a potentially useful natural enemy of nematodes, the *Pasteuria* bacterium. This has a saucer-shaped spore that sticks to the nematode's body and pierces it with a tube. The mature nematode is rendered infertile, its body being filled with bacterial spores instead of eggs. The studies conducted so far have shown that, if the bacterium is to prove effective as a means of controlling nematodes, its diversity must be preserved.

Soil solarization gives effective control.

One control method that has already proved effective in killing nematodes is soil solarization. The soil surface is covered with a polythene sheet, trapping solar heat. Polythene is too expensive for resource-poor farmers growing subsistence crops over relatively large areas. But the technique has been picked up by commercial farmers, nurseries, and market gardeners growing small plots of high-value cash crops such as tomatoes and vegetables.

Where do we go from here?

To spread awareness of the nematode problem and to help identify future research priorities, Sharma devised a questionnaire and sent it to many national research systems and to international and regional organizations. He also conducted a literature review, consulted world databases, and organized an international meeting on diseases caused by nematodes. The outcome will be a paper, authored with two colleagues at CAB International, summarizing the global state of knowledge on nematode pests of major food crops.

The paper argues that, although nematodes are receiving more attention than they did a decade ago, they are still under-researched. There is good reason to believe that nematodes will become a more serious problem in the future, as cropping systems intensify. An intensified global research effort is therefore long overdue.

Thanks to the efforts of Sharma and his colleagues, nematodes remain out of sight – but they are no longer out of mind.

Forging Ethiopia's future

Unlocking the potential of Ethiopia's 13 million hectares of Vertisols could transform the country's ability to feed itself. The Joint Vertisols Project (JVP), in which ICRISAT is a partner, is conducting research to fine-tune relevant technology and overcome adoption problems.

S Chater

Life is now easier for Degitu.

Conversion

When Becha Karorsa began sowing wheat in June, his wife Degitu attempted suicide. She had begged him not to try growing the crop, that had never been produced in their area before. "You're mad", she said. "It's far too risky. Our neighbors are saying we'll starve".

But her husband persisted in his folly. Under the guidance of staff of the Sasakawa-Global 2000 Project, he agreed to be the first farmer in his area to test a new implement, the broadbed maker (BBM). This, he was told, would enable him to grow additional crops and achieve dramatic increases in yields. While he was out in the fields, testing the BBM for the first time, Degitu drank a bottle of insecticide.

Rushed into hospital, Degitu was saved by stomach pumping. Later that year, a profitable harvest of wheat and other crops brought the family new prosperity. They now boast a new house with a tin roof, a fine new horse, and an expanded fleet of donkeys. Best of all, Becha has had a well sunk close to the homestead, saving Degitu a long walk to fetch water.

Today, you could find no more staunch supporter of the BBM than Degitu. She has even assisted her husband in his efforts to train other farmers in its use. Her conversion to the cause is a dramatic illustration of the change in attitudes that must accompany successful adoption of the BBM. For although the design of the new implement is simple, its use implies a revolution in cropping practices.

Break with tradition

The thick black clay soils or Vertisols of Ethiopia are fertile but difficult to manage. When rains start they rapidly become a quagmire in which plowing oxen flounder. By the middle of the rainy season they are waterlogged. As a result most farmers, if they cultivate Vertisols at all, delay sowing until late in the season, raising a traditional crop such as teff or chickpea on residual soil moisture.

Combined with limited use of inputs, late sowing leads to low yields. In addition, the soils remain open to sheet and gully erosion at the height of the rains. The result is poverty today – and a rapidly deteriorating resource base that threatens even greater poverty tomorrow.


P Pathak

Waterlogged Vertisols cannot be cropped during the main rainy season.

The key to increased productivity and long-term sustainability is better soil drainage. One way of achieving this is through broadbed-and-furrow, a cultivation technique in which raised beds retain enough moisture for the crop while excess water runs down the shallow channels left between them.

In theory, broadbed-and-furrow permits several types of productivity gain, promising a substantial increase in incomes and living standards. Starting earlier in the season, farmers can grow a wider range of crops and achieve higher yields from them. The time gained also allows them to grow an additional crop, doubling output from their land. The biggest prize at present is the opportunity to venture into wheat, a profitable cash crop previously ruled out by waterlogging. But the extra crop could also be a forage or dual-purpose legume, bringing added gains in soil fertility as well as food security and/or animal feed. The more stable conditions for cropping should encourage farmers to invest in improved crop varieties and fertilizers, boosting yields still further. Lastly, if the extra water drained from farmers' fields is stored, it can be used further downstream to irrigate a high-value fruit or vegetable crop during the dry season.

The potential environmental benefits are no less impressive. With the soil covered during the rainy season, erosion can be greatly reduced. In the longer term, the extra productivity on Vertisols on the lower slopes of watersheds could halt the relentless expansion of cropping into higher-lying forested areas.

To realize these benefits, however, farmers must cultivate and sow as soon as the first rains come. They must then control weeds, which establish rapidly during the rainy season and can quickly smother the young crop. Finally, they must be prepared to replace the nutrients extracted from their soils by the extra crop – using either chemical fertilizers alone or a combination of fertility-improving technologies. They may also need to apply pesticides to protect their yields.

All of which adds up to a substantial break with tradition. Not surprisingly, many farmers hesitate to adopt the whole package at once.

Technology development

ICRISAT's research on Vertisols began in India in the mid-1970s. The scientists soon found that broadbed-and-furrow could deliver the same yield gains in Asia as it had in Texas and Australia, where the technology originated. But to cultivate the beds they developed a wheeled tool-carrier, an implement that proved too expensive for most smallholders.

A decade later, researchers at the International Livestock Research Institute (ILRI) began exploring the feasibility of transferring broadbed-and-furrow to Africa, starting in Ethiopia. Aware of the need to keep investment costs low, they turned to Ethiopia's long tradition in the use of animal traction for solutions.

By the late 1980s, a consortium of national and international institutions had come together to form the Joint Vertisols Project (JVP), with the aim of increasing the productivity of Vertisols while protecting the natural resource base. The consortium's efforts resulted in a simple adaptation of the traditional *maresha* plow in which a curved wooden wing or moldboard replaced the traditional flat wing. This

was twice remodelled to arrive at today's version – two *mareshas* joined together in a triangular shape, with the moldboards linked by a chain at the back. Doubling up the *maresha* allows two furrows to be plowed at the same time, resulting in a substantial efficiency gain. Tested on farmers' fields at four locations, the new implement greatly reduced the labor requirements for seedbed preparation and sowing, allowing farmers to use the narrow window of opportunity available for cultivating Vertisols during the early rains. At all locations, use of the BBM substantially increased crop yields.

ILRI's research on the livestock component was complemented by the cropping systems research of the other JVP partners, including ICRISAT, the Ethiopian Institute of Agricultural Research (IAR) and Alemaya University of Agriculture. These institutions developed and tested improved varieties of wheat, teff, chickpea, and other crops, devised recommendations for fertilizer use, explored the effectiveness of various options for controlling weeds, and investigated different crop rotations and combinations for their potential to maintain soil fertility and combat pests and diseases. The result was a set of technology options that would enable farmers to derive maximum benefits from the use of a BBM.

After the fall of the Mengistu regime in 1991, the new Ethiopian Government declared broadbed-and-furrow cultivation to be one of several technologies ready for widespread dissemination by the extension services and non-governmental organizations (NGOs).

S Chater

IAR has developed new wheat varieties.

Swords into plowshares

The farmers call him "Ato BBM" – Mr Broadbed Maker. Fredawek Debele, a former ILRI employee, now has his own small business manufacturing the implements and training farmers in their use. Typical of the flourishing entrepreneurial culture of post-Mengistu Ethiopia, he's enthusiastic about his product and loses no opportunity to talk about it.

"Anyone you ask here will know about BBM", he says proudly. He's talking about Tulubollo, a village 50 km southwest of Addis Ababa in the fertile plains of the upper Awash valley, where around 5000 farmers have recently adopted the technology. This is one of several areas in the center, west, and north of the country where adoption has been widespread.

Debele is coy about the number of BBMs he has sold. But his thriving business is clear evidence that demand for the technology is creating a knock-on effect in the Ethiopian economy. His biggest customer is probably the Ministry of Agriculture, which in 1995 ordered 20 000 implements. These are being distributed in collaboration with Sasakawa-Global 2000, an NGO that employs Debele to train farmers.

With an estimated 20 000 to 30 000 farmers now having been exposed to the technology, the BBM looks set to become big business in rural Ethiopia. Would-be manufacturers up and down the country have asked Fredawek for advice on how to make it. In Pawe, close to the frontier with Sudan, blacksmiths hungry for metal to forge the chains cannibalized wrecked Russian tanks that lay rusting by the roadside – vestiges of Ethiopia's protracted civil war. It's just one example of how the country's new enterprise culture is encouraging its people to turn their swords into plowshares.

Hasten slowly

Despite the urgency of Ethiopia's food needs, many observers caution against pushing ahead with technology transfer too fast, without sufficient attention to the problems that can accompany adoption.

Around 80% of farmers testing the BBM complain that it is too heavy to handle. Its designers take this seriously: "For as long as people are telling us this, we should continue our efforts to develop a better model", they say. But for Debele the problem indicates the need for training. "Farmers buy the implement, then find they don't know how to use it", he says. "It's a different technique from ordinary plowing."

Handling problems also reflect farmers' caution in adopting the new technology, according to Marcos Quinones, who heads the Sasakawa-Global 2000 project. "Use of the BBM must coincide with sowing, but it's difficult to persuade farmers to sow in June instead of August or September. They see it as too risky. As a result they try to use the BBM too late, when soils are waterlogged". Quinones believes that farmers are slowly moving their sowing dates back as they gain confidence.

Another problem is that not all seasons are suitable for BBM cultivation. In 1996, for example, the rains came in so hard and so fast that farmers were taken by surprise and missed their opportunity to cultivate.

Nor are all Vertisol areas appropriate for the technology. Furrows made on completely flat soils will not drain excess water. And on slopes that are too steep, opening furrows without adequate precautions increases the risk of erosion.

Worst of all, the technology could yet be a victim of its own success. In watersheds where adoption is widespread, the extra water drained from farmers' fields could exacerbate problems of waterlogging and erosion further down the slope. Broadbed-and-furrow could prove a highly divisive technology in communities where some farmers have watched their topsoil being washed away by floodwater from their neighbors.

Problems of this kind have already been observed at Ginchi, a watershed west of Addis Ababa where IAR carried out on-farm trials. Now Ginchi is the site of a new experiment in participatory research in which ICRISAT and its partners sought consensus for interventions from the whole community.

Saving a threatened watershed

Aerial photographs provide irrefutable evidence that the fringe of forest on the slopes above Ginchi is in retreat – pushed back each year as farmers clear land further and further up the slope. Pasture areas on the lower slopes are also steadily disappearing under the plow. The result is a watershed whose gullies grow deeper and longer each year. A baseline study showed that, between 1980 and 1994, an extra 5.2 km of gullies had come into being, bringing the total to 14.5 km in an area of only 45 ha.

JVP scientists set to work with the farmers to design and build a new drainage system that would divert runoff and halt erosion. After a topographical survey, they conducted an inventory that showed how complex the task would be. The 45-ha area contained 149 fields cultivated by 64 farmers, none of whom wanted the drains to cross their land! The reason was that this would incur the loss of valuable crop production. It took five meetings over a 6-month period to reach agreement on the solution, which was to route the drains along the footpaths that delineate field boundaries.


M C Klaij

A V-notch device measures runoff at Ginchi.


P Pathak

Farmers build the main drainage channel at Ginchi.

It was May by the time the final design was agreed. Using picks and shovels, the farmers immediately began work on the main drain, but it soon became obvious that the task would not be completed before the rains came. A tractor-mounted plow was therefore used to break the soil surface along the compacted footpaths. This raised morale and the rest of the digging and shaping was completed on time. The drains have now been lined with grass.

According to JVP scientists, the new drainage system has already made a difference. Farmers are pleased that their land is better drained, and have noticed that a large gully near the bottom of the watershed has been stabilized.

With the drainage system in place, the scientists invited all farmers to participate in large-scale demonstrations of broadbed-and-furrow. Following a 1-day training exercise in the use of the BBM, the farmers received seed and fertilizers on credit, to be repaid after harvest. A similar scheme was launched at nearby Gimbichu.

The trial results at Gimbichu confirmed the substantial yield gains that can be achieved when farmers apply all aspects of the package successfully. Durum wheat growth was spectacular, with yields well above the national average. Results at Ginchi were less impressive, probably reflecting the use of an insufficiently adapted wheat variety.

The experiences at Ginchi and Gimbichu show that Ethiopian farmers can be motivated to work together to plan and implement improved drainage, preparing the way for the safer use of broadbed-and-furrow on a watershed basis.

Ethiopia's green revolution

Crop production in Ethiopia rose by over 30% in 1995. And the country is heading for another record-breaking harvest in 1996.

In the vanguard of Ethiopia's green revolution are the thousands of farmers who are now experimenting with the early sowing of improved wheat and other crops. Many of the technology options they are using – crop varieties as well as cultivation techniques and implements – were developed by the international agricultural research centers and their national research partners. ICRISAT is proud to have played its part in this success story.

National researcher trains ICRISAT staff

In a reversal of the conventional relationship between international and national researchers, ICRISAT technicians have received training from the head of Colombia's sorghum breeding program.

A neat technique

Jamie Bernal can tell at a glance whether the sorghum plants he is screening will be able to tolerate the toxic soils found in the savannas of his home country. He simply lifts them clear of the aluminum bath in which he keeps them, and looks at their roots. Tolerant plants have good strong white roots. Those that are not tolerant – the vast majority – have feeble, blackened root systems.

The difference is a crucial one. Tolerance to aluminum toxicity is the single most important trait in improved sorghum varieties intended for the acid-soil savannas of Latin America. Plants without this trait are unable to obtain water and nutrients and soon die. Sorghum first arrived in the region less than 200 years ago, probably from areas of Africa where acid soils are not a problem. As sources of tolerance within the region are scarce, countries with large savanna areas, such as Colombia, Venezuela, and Brazil, need to look elsewhere for them.

Bernal developed his greenhouse technique for screening sorghum for aluminum tolerance while doing his masters degree at the University of Nebraska in the early 1990s. The technique is really an adaptation of methods developed earlier for wheat by the Centro Internacional de Mejoramiento de Maïz y Trigo (CIMMYT). Although simple and accurate, it is a sensitive one requiring certain skills. Practitioners must find the right concentrations of chemicals and store them at the right temperature in order to simulate the soil conditions for which they are screening. They must also know how often to change the solutions.

Greenhouse screening saves time, space, and money.

An uncompleted task

Bernal's degree at Nebraska was funded by the USA's International Sorghum/Millet Collaborative Research Support Program (INTSORMIL), which at the time had a regional sorghum breeding program based at the Centro Internacional de Agricultura Tropical (CIAT), near Cali, Colombia. Developing material with aluminum tolerance was a central component of the program, which screened around 8000 lines imported to Colombia from the world sorghum germplasm collection, held at ICRISAT Asia Center.

But in 1993 the program fell victim to funding cuts and was closed. The task of screening remained incomplete, with only a few aluminum-tolerant lines identified.

Savings

In 1996, the Inter-American Development Bank agreed to fund the first two years of a new five-year sorghum breeding project proposed by ICRISAT, INTSORMIL, and CIAT. The project is essentially a resurrection of its predecessor. One of its main objectives is to complete the aluminum toxicity screening work.

Previously, ICRISAT's scientists had sent all lines for screening directly to CIAT, where they had been evaluated in the field. This time round, Bernal was keen to put into practice the greenhouse technique he had earlier developed. Besides giving more reliable results, this would save time, space, and – most important – money. The greatest savings could be effected by using the technique to conduct a pre-screening exercise in Asia, so that only those lines that appeared tolerant need be sent to Colombia.

There was just one snag: no one at ICRISAT was familiar with the technique. Accordingly, Bernal spent five months at ICRISAT Asia Center, training two technicians in the necessary skills, and conducting some initial screening.

Now he's back in Colombia, running tests to find out whether lines that appeared tolerant when screened in the greenhouse in India perform in the same way when grown in the field. The results will tell him whether the screening technique has been correctly set up. When he gives the thumbs up, ICRISAT's technicians will get to work.

While imparting his skills to others, Bernal took advantage of his long stay at ICRISAT to gain greater familiarity with several other areas of sorghum and pearl millet research, including the use of molecular markers. He's looking forward to expanded collaboration with ICRISAT in the future.

More fertile African soils: it can be done

Can research make a difference to fertilizer use in resource-poor farming systems? Scientists based at the ICRISAT Sahelian Center have been finding out.

Doomsday scenario

Fertilizer use in Africa remains disturbingly low. Asian farmers apply nearly 10 times more phosphorus to their crops than do African farmers – 15 kg ha^{-1} of arable land compared to 1.6 kg ha^{-1}. Recent progress in African agriculture seems doomed to stall unless this statistic can be improved, and some observers have warned that African production systems are heading for total collapse if farmers do not change their ways.

The situation is particularly worrying in the drought-prone Sahelian zone of western Africa, where most resource-poor farmers 'mine' their soils by monocropping cereals year after year with little or no use of inputs.

A learning experience

So eager were the farmers of Gobery to obtain commercial fertilizers that they clubbed together to hire a truck. They left their small village in southern Niger at dawn to drive south to Nigeria, hoping to load up with supplies over the border. But the farmers returned home empty-handed. In Nigeria as in Niger, no fertilizers could be found on the market that year.


S Chater

Farmers must use more fertilizer to ensure the long-term productivity of Sahelian soils.

Mistrust of fertilizers as too expensive to be worth the risk is part of the stock image of farmers in the African drylands. In wetter areas, farmers often apply fertilizers to maize or cash crops, but they seldom do so to the staple cereals of the semi-arid zone, pearl millet and sorghum.

So what makes the farmers of Gobery different? The answer is that, having worked alongside researchers for the past 13 years, they have learnt to overcome their mistrust. When ICRISAT and the International Fertilizer Development Center (IFDC) began joint on-farm research there in 1984, use of fertilizers was limited to the 30 participating farmers, who received them as part of the package being tested. By 1994, every farmer in the village was buying fertilizers independently of IFDC and ICRISAT. Consumption had risen from less than 2 tonnes of single superphosphate (SSP) to over 150 tonnes of SSP, urea, and NPK fertilizers. In short, the village had undergone a quiet revolution in its attitude to inputs.

The farmers have adopted several other innovations that enhance both the productivity and the sustainability of their mixed crop-livestock production system. Eighty-six of the village's 136 households now plant cowpea in rotation with pearl millet instead of monocropping pearl millet. And the use of millet straw as a mulch and a source of nutrients has become widespread.

The changes at Gobery show what can happen when farmers are exposed to new practices and are given sufficient time in which to learn how to use them. They demonstrate powerfully that the non-use of fertilizers is primarily a knowledge problem – one that could be overcome through increased demonstration and training backed up by media campaigns.

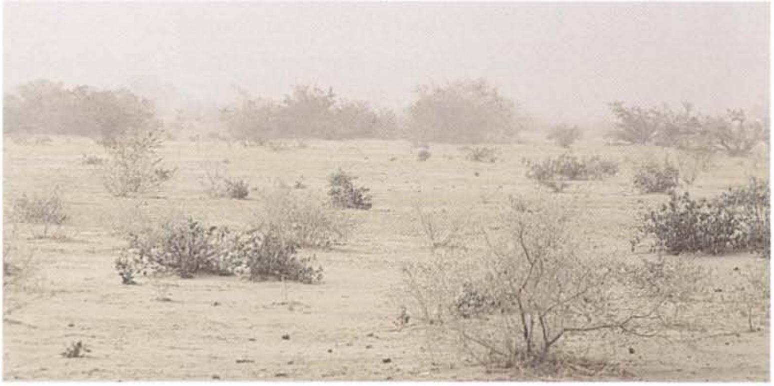

A Bationo

Phosphorus is the key nutrient.

A rock and a hard place

The key nutrient for improving the fertility of western Africa's sandy soils is phosphorus. The region has ample reserves of rock phosphates, but in most countries these remain underexploited.

The reasons lie partly in the fact that phosphate rock is a raw material. It has a lower content of available phosphorus than pure commercial fertilizers and must



S Chater

Blowing in the wind...the Sahel's weather conditions frustrate farmers' attempts to apply rock phosphate.

be ground to a powder before it can be applied, incurring high processing costs. The rock's characteristics vary greatly from one deposit to another: some are very hard and do not grind easily or dissolve rapidly in the soil. When applied in farmers' fields they release phosphorus only slowly, so yield gains in the short term may disappoint farmers hoping for spectacular harvests.

The dry, windy conditions of the western African Sahel don't help either. Lack of soil moisture compounds the solubility problem, especially where soil acidity is also low. And, as they watch the fine powder they have scattered on their fields being whipped up into a chalky haze, farmers often complain that they have benefitted their neighbor's crops, not their own. Attempts to solve these problems by manufacturing granules instead of powder have met with limited success, mainly because granules have less surface area in contact with the soil and therefore dissolve even more slowly.

Since neither the rock itself nor the harsh environment in which it is applied are conducive to easy use, farmers – if they use fertilizer at all – often revert to conventional commercial products such as single or triple superphosphate, brought up from the western Africa's coastal ports. Yet the research of ICRISAT and IFDC at Gobery and other locations in Niger suggests that the region's vast deposits of phosphate rock need not be simply left in the ground.

Encouraging results

Niger has two phosphate mines, one at Tahaua in the center of the country and the other at Tapoa, in the south-east. Phosphate from Tapoa is known as Parc-W, after the W-shaped national park along the frontier with Burkina Faso and Benin in which the mine is situated. Both Tahaua and Parc-W phosphate were tested in the IFDC/ ICRISAT's trials, together with a third rock phosphate imported from Kodjari, in Burkina Faso.

Of the three, Tahaua is the softest, dissolving most easily in the soil. On-station trial results showed that it can be up to 80% as effective as SSP, depending on favorable rainfall and soil conditions. At one third the price of commercial SSP – US$ 4.44 compared with US$ 14.20 for a 50-kg bag – Tahaua rock phosphate thus represents a better deal for farmers than reliance on commercial fertilizers alone.

The on-farm trials also showed that application problems can be overcome. Participating farmers learnt to apply the powder on windless days and to incorporate it into the soil immediately.

Even better news for farmers was that mixing phosphate rock with commercial fertilizers resulted in strong synergy between the two. At Gobery, broadcasting 13 kg ha^{-1} of ground Tahaua rock phosphate before sowing allowed the same pearl millet yields to be achieved with just 2 kg ha^{-1} of P applied as SSP while sowing as those obtained using 13 kg ha^{-1} of P applied as SSP alone. Cost-benefit analysis showed that this practice was the most profitable across all locations, because of its low cost. This means that farmers can apply rock phosphate as a long-term capital investment in their soils while drastically reducing the amount of imported commercial fertilizers needed to obtain satisfactory yields in the short term.

Rotation, mulching, and incorporating crop residues further improved the efficiency of both rock phosphate and commercial fertilizers at all locations. At Gobery, farmers adopting these practices increased their yields by an impressive 250%.

Most encouraging of all was the effect of these practices on the long-term sustainability of the system. Over a 13-year period, combining commercial fertilizers with the incorporation of crop residues more than doubled pearl millet yields, widening the gap between this and other treatments (Fig. 1).

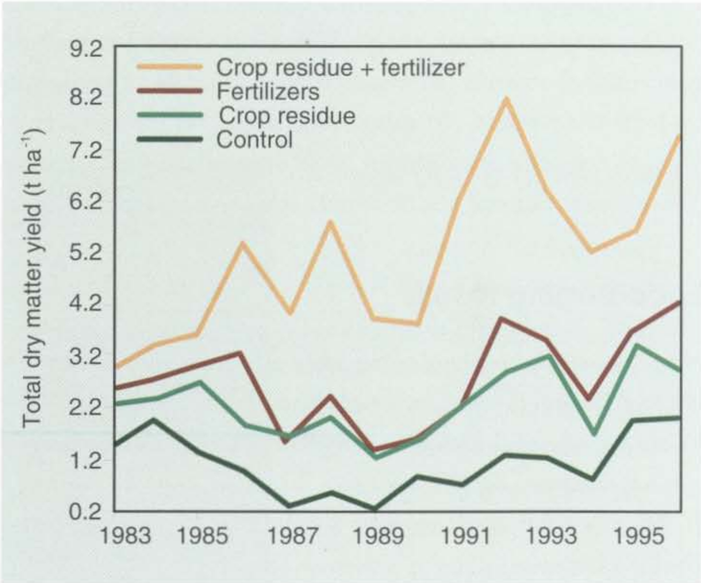


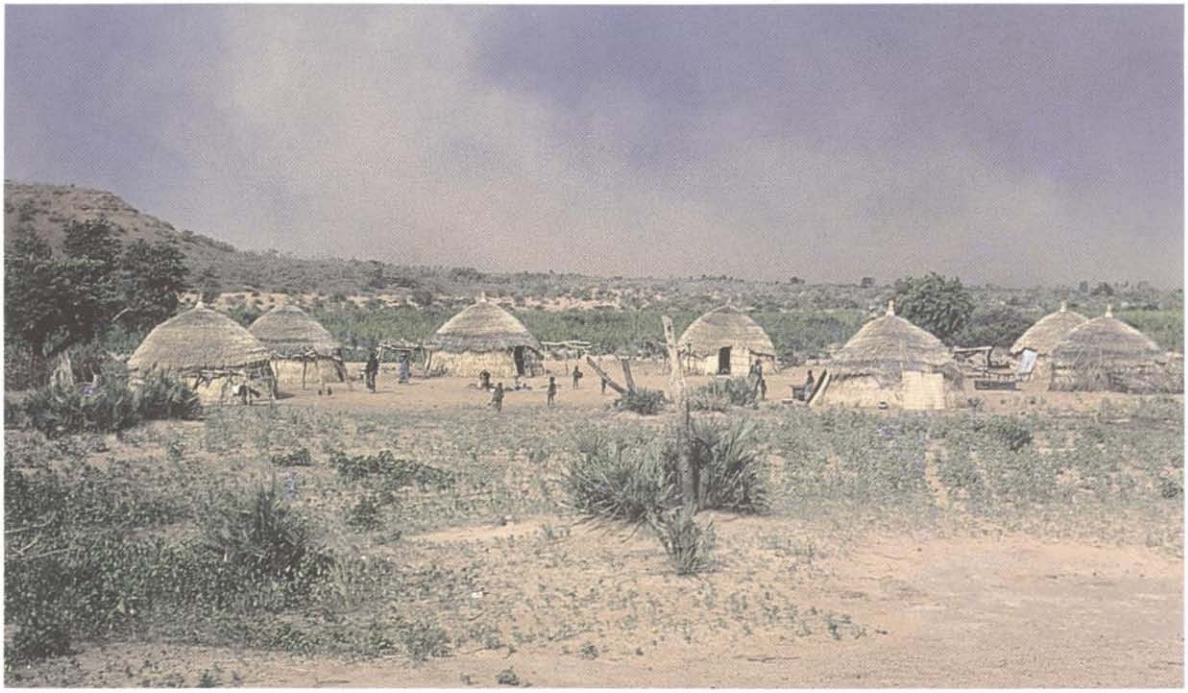
Figure 1. Dry matter biomass of pearl millet as affected by different management practices.

Lessons

The on-farm trial results have taught the farming community at Gobery two invaluable lessons. First, the use of fertilizers is more profitable and less risky when part of a package of sound management practices that enhance system sustainability. Second, sizeable efficiency gains can be achieved by using rock phosphate as a component of the overall package.

These lessons, in turn, carry important implications for researchers, extension workers, and policy makers. The crucial role of other management practices in ensuring effective and sustainable use of fertilizers means that training and educating farmers is vital for success. As the experience at Gobery shows, a participatory approach in which the farmers define and promote innovations that lie within their means will be most effective.

Commercial fertilizers are bought with scarce foreign exchange, placing them beyond the reach of most farmers, especially since the recent devaluation of the CFA franc. Recently, there has been renewed donor interest in the exploitation of the region's phosphate rock. It is high time that this indigenous resource took its rightful place at the center of national soil fertility management strategies.



M C Klaij

Declining soil fertility is a major constraint to sustainable increase in food production in SAT Africa.

What do farmers want?

Farmer participation in the design of new crop varieties is essential if these are to meet users' needs – as sorghum and pearl millet researchers in southern Africa are discovering.

Devastated

The small plot of Okashana 1 lay devastated. Most of the plants had fallen over. Not a head of grain remained.

Yet as he surveyed the scene, ICRISAT's pearl millet breeder could not suppress a sigh of satisfaction. The cause, after all, was not bird or insect attack but marauding farmers. At the end of their visit the farmers had been invited to revisit the plots they had inspected earlier and to take away a head or two of the genotype that most appealed to them. The result had been a stampede towards Okashana 1, a new short-stemmed, early-maturing pearl millet variety originally selected in Namibia and now being tested in Zimbabwe. It was the clearest possible evidence that, if released in Zimbabwe, Okashana 1 would prove highly popular with farmers.

Novel exercise

The farmers who had taken such a liking to Okashana 1 were taking part in a novel exercise in participatory on-station research at the Matopos Research Station, home to the SADC/ICRISAT Sorghum and Millet Improvement Program (SMIP).

To carry out the exercise, the scientists had devised a new type of nursery – the diverse germplasm observation nursery. The purpose was to expose the farmers to as many contrasting plant types of sorghum and pearl millet as possible, so as to gain insights into the traits important to them.

Each farmer was asked to tour the nurseries with a score card, rating each plant type between 1 and 5 for a range of listed traits. A final column on the card asked them to state the reasons for their rating.

After the workshop, the scientists analyzed the farmers' remarks on each genotype to identify the main criteria they had used in their evaluations. They also measured each genotype's agronomic characteristics, so as to be able to quantify what the farmers meant.

The exercise has now been conducted for 3 years running in Zimbabwe. And the scientists have gone on to hold similar events in Namibia and Tanzania.

Intriguing results

The results so far confirm that SMIP's breeding objectives are in line with what farmers want. The exercise for sorghum in Zimbabwe, for example, showed that farmers' preferred traits are, in order of priority, short to medium plant height, drought tolerance, early maturity, large grain size, and high yield (Fig. 1). These are the characteristics of several improved varieties developed by the program and its partners, including SV 2 in Zimbabwe, Macia in Mozambique, and Phofu in Botswana.

Plant height is, of course, a proxy for other characteristics. Low stands make bird scaring easier, especially for children. They are also easier to harvest. And there is a

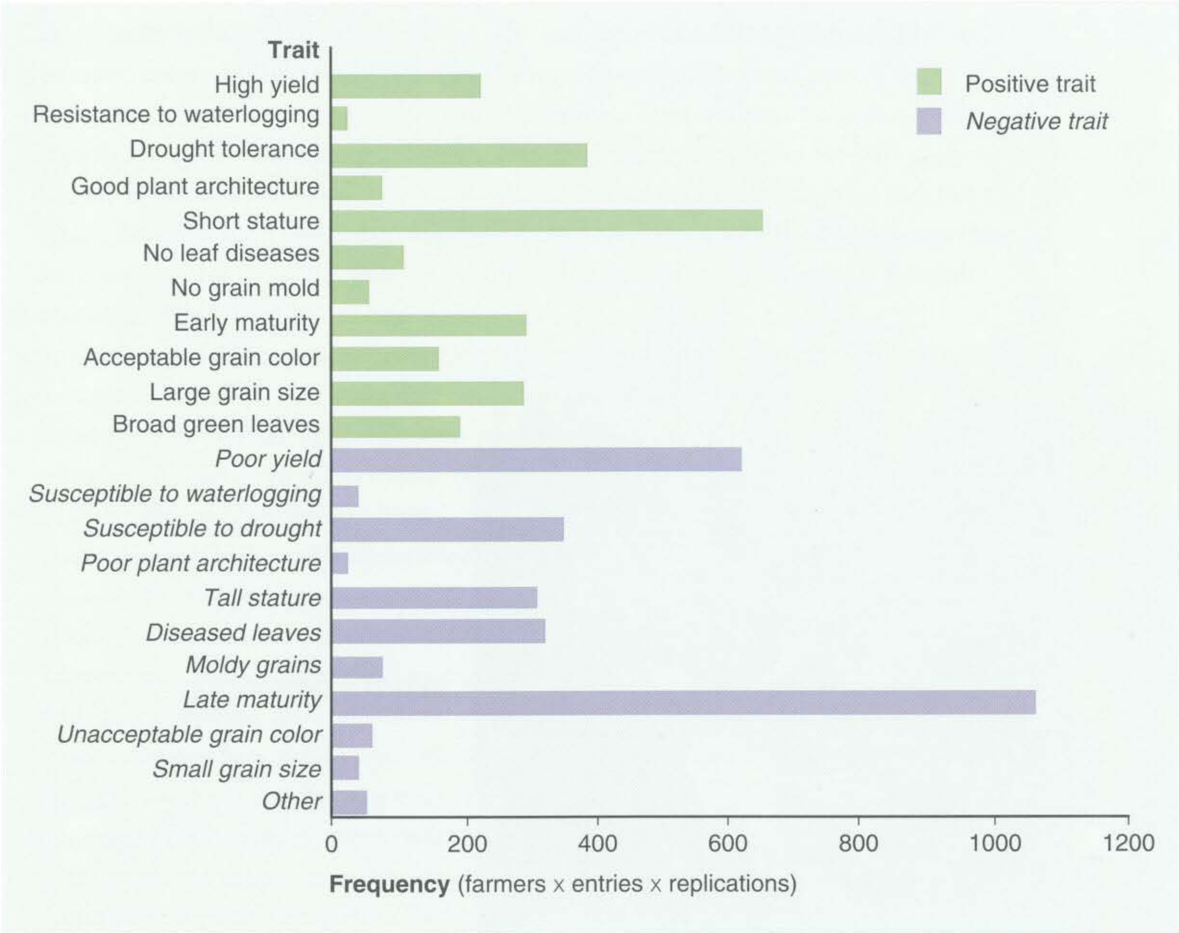


Figure 1. Positive and negative traits most frequently mentioned by farmers observing sorghum nurseries at Matopos and Lucydale, Zimbabwe, 1993/94 and 1994/95.

high correlation between height and time to maturity, with late varieties tending to grow tall. The same logic applies to several other priority traits.

Earliness provides farmers with the option of playing it safe – shifting from higher-yielding but riskier late-maturing varieties to earlier-maturing ones that will sustain them in their often drought-prone environments. Earliness also offers them an option to sow these riskier late-maturing varieties first, complementing them with a later sowing of the earlier-maturing new varieties. This strategy improves the probability of harvesting at least some grain, spreads the demand for labor more evenly over the season, and offers higher returns when rainfall is favorable.

The results nevertheless reveal a significant difference of emphasis between farmers' priorities and those traditionally adhered to by plant breeders. Breeders, at least of the old school, tend to focus narrowly on yield, whereas for farmers a range of other traits appears more important.

This finding has implications for some breeding programs in the region, especially those taking a "quantum leap" approach to increasing crop yields. Such an approach works well for crops grown mainly or exclusively for food, such as wheat, but is less suitable for those like sorghum and pearl millet, that have multiple uses. In these crops it appears better to go for small yield gains accompanied by preferred traits than for large gains that may exclude them.

Yield is, however, still an important criterion for farmers, especially those trying to feed large families and produce a surplus for sale. It should therefore be retained as a breeding objective and not discarded altogether, as some critics of formal plant breeding programs have suggested.

A B Obilana

Farmers enjoyed the evaluation exercise.

What's different?

In the Zimbabwean exercise, the responses of farmers from different districts were remarkably consistent for most priority traits. Surprisingly, there was consistency even with regard to that most subjective of traits – taste.

Traits on which there was more divergence included grain color and aroma. The different opinions on color probably reflect the different end uses of the crop – red sorghums are used for beer while white are consumed as food, for example. Differences on aroma appear to be more purely subjective.

The exercises threw up some interesting differences between countries. Zimbabwean farmers, for instance, don't like tall varieties of pearl millet because of their vulnerability to bird attack. In Namibia, on the other hand, the short-stemmed Okashana 1 variety has proved less popular with farmers than expected, partly because its stalks are not long enough to be used as fencing. The preference for a taller plant suggests that birds are less of a problem here.

Gender was another factor explaining differences. In Namibia, men voted for one variety of pearl millet which they found to be more delicious than all the rest. But this variety is difficult to dehull, a task which traditionally falls to the women. They rejected the variety because of its extra labor requirement.

Methodological issues

SMIP's breeders are the first to admit that they have some way to go in refining the methodology for involving farmers in technology design. Their experiences raise several important issues.

Getting reliable answers to questions depends critically on the representativeness and suitability of the farmers selected for the exercise. The first year's results for pearl millet at Matopos had to be discarded, as the group invited to the station had consisted entirely of men, whereas over 60% of Zimbabwean farmers are women. Farmers also need to be experienced in the crops concerned, to have good analytical powers and to be honest and articulate about their feelings and aspirations.

One limitation of the nurseries is that they allow farmers to react only to what they can see. The value of such hidden characteristics as resistance to diseases cannot be assessed. Nor are farmers encouraged to imagine completely new types of plant or to express opinions about the more subtle physiological responses of plants to their environment. These are areas in which scientists have a comparative advantage over farmers in assessing needs.

Several factors could cause variations in farmers' responses over time. Foremost among these is the weather. The Namibian nurseries, for example, were run in a year when the rains came very late. That may have predisposed farmers to select early-maturing types which, in a wetter year, they might have discarded. Changing market demands may also influence farmers' choices. Farmers in Namibia can be expected to show increasing interest in white-seeded varieties of pearl millet if the new market there for better quality flour and packaged cereal products takes off. Finally, like small business folk anywhere, resource-poor farmers are more inclined to try something new when things are going well for them, but will tend to be more conservative in their choices when times are hard.

Such factors are difficult to detect and analyze, reinforcing the case for repeating evaluation exercises among the same farmers every few years. Given that it takes 10 years to develop a new crop variety, it is vital that scientists receive early warning of possible changes in farmers' priorities.

Another critical methodological issue is whether such exercises should be conducted on-station or on-farm. The advantages of an on-station exercise lie in the lower cost of establishing nurseries and the ease with which farmers can be exposed to a wider range of materials. In addition, the results are usually more reliable because nurseries can be managed uniformly and the evaluation process more strictly controlled.


Many farmers in Zimbabwe are women.

But SMIP's breeders see more exercises taking place on-farm in the future. Only a few farmers can be brought to the research station. Placing the nurseries in the village allows the whole community to express its opinions, and to change them as they watch the crops mature during the season. An important additional benefit is that farmers become the custodians of biodiversity in their own fields.

One point to emerge strongly from the experiences so far is the wisdom of the newer approaches to plant breeding that have emerged in recent years. Instead of pursuing a single plant ideotype that they hope will be universally adopted, most breeders now seek to develop a range of options to suit different ecological and socioeconomic niches.

The case of the inactivated wasp

Why do the natural enemies of the podborer not attack it when it's on pigeonpea? A visiting scientist from Germany's Höhenheim University has been finding out.

A puzzle

Now resistant to most synthetic pesticides, the podborer (*Helicoverpa armigera*) causes heavy yield losses in food legumes throughout Asia's semi-arid tropics. In search of alternatives to chemical control, scientists at ICRISAT and elsewhere have investigated several of the pest's natural enemies.

Among the promising candidates are *Trichogramma* egg parasitoids, minute parasitic wasps that land on plants likely to be infested with *Helicoverpa* and move about in search of its eggs. On finding the eggs, the wasps pierce the shells, laying their own much smaller eggs inside. The *Helicoverpa* eggs are destroyed as the parasitoids develop within their host. Eventually the wasps emerge to fly about, feed on plant nectar, mate, and repeat the cycle.

Pigeonpea pods damaged by the pod borer Helicoverpa.

But as they investigated *Trichogramma*, the scientists encountered a puzzle. The wasps are efficient at reducing *Helicoverpa* on such crops as sorghum, tomato, and cotton – but not on pigeonpea. Whereas levels of up to 70% parasitization of *Helicoverpa* eggs were recorded on sorghum, the figure was only 1% on pigeonpea.

Pigeonpea and sorghum are often intercropped in the semi-arid tropics of Asia. The scientists had originally hoped that, if *Helicoverpa* suffered high parasitization levels on sorghum, the parasitoids would spread with their hosts from the sorghum to the pigeonpea, providing some degree of control for both crops.

In 1993, a postdoctoral fellow at ICRISAT apparently succeeded in getting this strategy to work. In an experiment on the research station at ICRISAT Asia Center, he found parasitism levels of up to 70% in *Helicoverpa* eggs laid on pigeonpea, when the pigeonpea was intercropped with sorghum.

Simple sticky traps help monitor pest populations.

Keen to capitalize on these encouraging findings, a visiting scientist from the University of Höhenheim, Germany, came to ICRISAT under a collaborative project funded by the Bundesministerium für Wirtschaftliche und Entwicklung Zusammenarbeit/Deutsche Gesellschaft für Technische Zusammenarbeit (BMZ/GTZ) to verify the results and to determine appropriate management practices. And that's when the problems began: the scientist was unable to repeat his predecessor's results. Using sticky traps – cylindrical glass tubes coated with transparent glue – to monitor *Trichogramma* populations, the scientist found out that pigeonpea did not benefit from a high parasitoid population on sorghum.

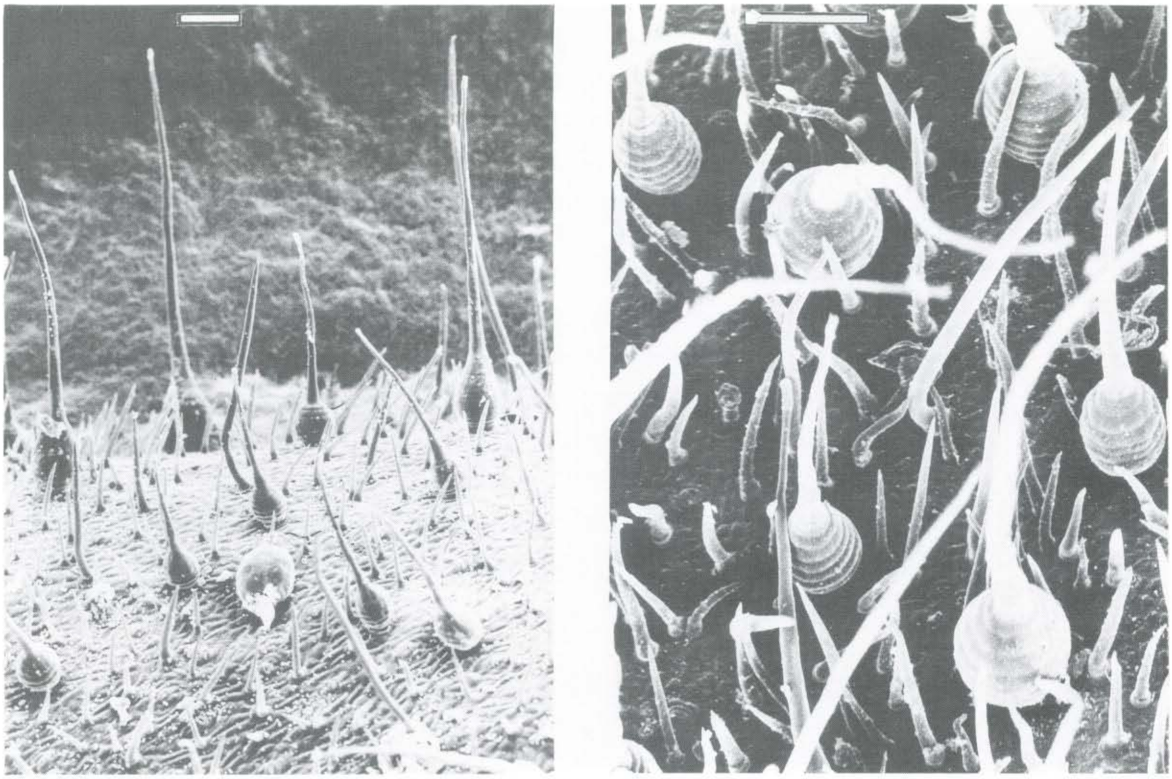
At first the scientists thought the explanation might lie in the flowering behavior of the two crops. Success depends critically on getting them to flower at the same time, as *Helicoverpa* prefers to feed only on the reproductive parts of plants. But this is tricky, as the two crops respond differently to environmental conditions.

Then, as they looked more closely at the relationship between the pest and its natural enemy, the scientists began to uncover the real reasons why *Trichogramma* is ineffective on pigeonpea.

Trapped in the forest

In laboratory studies, the scientists stuck *Helicoverpa* eggs on different parts of the pigeonpea plant in cages, into which they released *Trichogramma*. Parasitism levels on flower buds and pods, where *Helicoverpa* preferably lays its eggs in the field, were only 0–1%. In contrast, in the *Helicoverpa* eggs laid on leaves, parasitism levels averaged more than 50%.

A closer look at the pods under the microscope revealed that two physical factors were responsible for inhibiting the parasitoids. Both concern the trichomes or fine hairs that cover the pods of cultivated pigeonpea. These hairs, which may have evolved to protect the plant in some way, are of variable length – some tall, some short. Together they form a thick but uneven canopy over the pod surface, in which the visiting wasp stumbles and loses its way like an explorer in dense forest. As if this



A K Murthy

Scanning electron micrographs of the pod surface of pigeonpea showing different trichome types (scale: bar = 100 μm).

terrain were not already hostile enough, one of the three glandular hair types secretes at its tip a sticky exudate that traps and immobilizes any wasp that blunders into it.

To test the effectiveness of these two physical factors the scientists separated them by washing the pods, thereby removing the exudate. They found that, even on washed pods, the parasitic wasps were able to move only slowly compared to their normal speed on smooth-surfaced leaves. Their slow pace makes their random search for *Helicoverpa* eggs largely unsuccessful. As a result, few wasps that land on pigeonpea pods are able to initiate a new breeding cycle.

Smellbound

Complementing the physical factors were chemical barriers to parasitization. These the scientists discovered by using an olfactometer – an observation chamber whose four projecting arms connect to separate odor chambers containing different plant material or left empty (control). From the center of the observation chamber, air is sucked out, creating different "fields" of smells in the chamber. By studying how long an insect spends in each field, the scientists can find out whether it likes or dislikes the smell of different plants or plant parts at various growth stages as compared with the fields without any plant smell.

When the scientists placed sorghum leaves or panicles in two of the chambers, the wasps were "arrested" – that is, they elected to stay in those two olfactory fields, showing that they found the smells of these plant parts attractive. In the case of pigeonpea, the wasps showed no reaction when exposed to the smell of the plant's leaves, but quickly left fields associated with its flower buds and pods. Thus it would appear that, as soon as it enters the reproductive phase, the pigeonpea emits a volatile chemical that repels these helpful parasitoids.

This olfactory repellent is reinforced by a further set of chemicals that deter the few parasitoids that reach the pod surface. These chemicals remain unidentified at present. They may also be involved in the host selection process of insect pests like *Helicoverpa*.

Implications for control

Together, the two sets of physical and chemical deterrents make it highly unlikely that parasitic wasps would spread from sorghum to pigeonpea. This rules out the use of intercropping to control *Helicoverpa* on pigeonpea – even if the two crops could be made to flower at the same time.

This finding raised the question of how the first scientist had achieved his results. The question remained unanswered until the postrainy season of 1996/97, when – to everyone's surprise – large numbers of *Helicoverpa* eggs were recorded on pigeonpea leaves, where the parasitic wasps were able to get at them, causing parasitism levels of up to 80%. The first scientist had recorded parasitization levels without noting the plant parts on which the parasitoids had been found. The high proportion of *Helicoverpa* eggs laid on the leaves might have been due to the high *Helicoverpa* population which had built up in an adjacent chickpea field.

Although intercropping now looks unpromising as a means of control, the research did open up some new avenues to explore. One is the possibility of breeding pigeonpea varieties with less hairy pods, which would be more user-friendly for parasitic wasps. Interestingly, the glandular hairs that trap the wasps are likely to emit a chemical that stimulates the feeding behavior of *Helicoverpa*. Removing these hairs would simultaneously encourage the wasp while discouraging *Helicoverpa* infestation.

A second possibility is the use of sorghum as a trap crop for *Helicoverpa*. *Helicoverpa* preferred sorghum to pigeonpea; the moths moved on to pigeonpea when sorghum was no longer attractive. Staggered sowings of sorghum would extend the period during which the crop remains attractive to *Helicoverpa*, thus limiting the damage on pigeonpea.

An evolutionary riddle

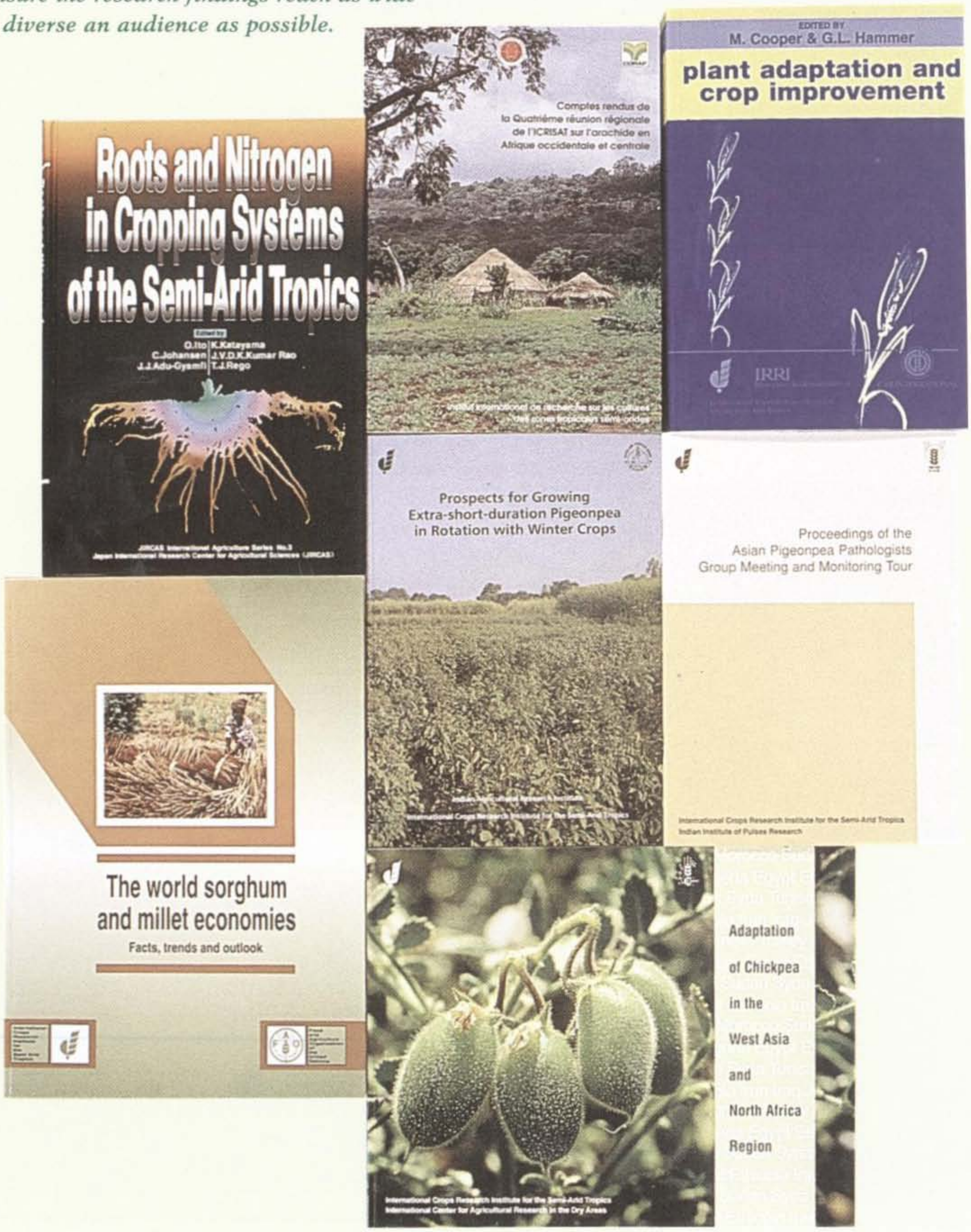
The pigeonpea plant is now highly effective at deterring its beneficial visitor, the parasitoid. It seems likely that this is an unintended side-effect, and that the plant's elaborate defence mechanisms originally evolved to protect it against other enemies.

What these enemies are – and how their behavior might change if new, hairless pigeonpea types were developed – remain unanswered questions, that should keep researchers seeking environmentally friendly answers to one of the major constraints to production busy for some time to come.

P Pathak

Hidden benefits – traditional sorghum/pigeonpea intercropping might have had benefits of which farmers were unaware.

In 1996 ICRISAT published the results of its work in association with national and international institutions, with sister CGIAR centers, with FAO, and with donors. This range of copublishers all have a common aim – to ensure the research findings reach as wide and diverse an audience as possible.



The year 1996 was a turbulent one for the Institute. At the Mid-Term Meeting (MTM) in Jakarta in May, it became apparent that ICRISAT's TAC-approved budget of US$ 28 m was going to be under-funded by almost US$6 m. As a result, an appeal for additional funds was made at the MTM, and several existing donors responded by extending a helping hand by increasing their 1996 contributions. These donors included Australia, which increased its support from US$ 0.522 m in 1995 to US$ 0.620 m in 1996, France from US$ 0.292 m in 1995 to US$ 0.804 m in 1996, and India from US$ 0.188 m in 1995 to US$ 0.587 m in 1996. The Republic of Korea revived its support to ICRISAT in 1996 after a gap of a few years.

However, amidst the financial doom and gloom, there were some bright spots. No less than three new donors agreed to support our work in 1996. Among them, the Common Fund for Commodities (CFC), headquartered in Amsterdam, undertook to support part of ICRISAT's research on groundnut germplasm in Western Africa and Latin America. We also welcomed first-time donations from the Government of the Islamic Republic of Iran, and we are especially grateful to a third donor, Denmark, who provided US$ 2.165 m in their initial year of support.

Following immediately after MTM, the Institute took steps to reduce expenditure and help contain the deficit. Firstly, a total of US$ 0.5 m was saved from the international staff cost by not filling either previously approved positions, or positions that became vacant during the year. Secondly, nonsalary budget allocations were reduced by a total of US$ 1.9 m across the Institute. To achieve this, several severe cost-cutting measures had to be undertaken. These measures led to an operating deficit in 1996 of US$ 2.5 m compared to an operating deficit of US$ 0.343 m in 1995. The deficit which was financed from operating fund, has put the Institute's finances in a precarious position. The balance on the operating fund, which represent the Institute's accumulated surplus to date now stands at US$ 0.167 m, equivalent to 2 days of normal operating expenditure excluding depreciation, compared to the CGIAR recommended level of 90 days. It is planned to build the fund to a level of about 30 days during the 1998–2000 Medium Term Plan period.

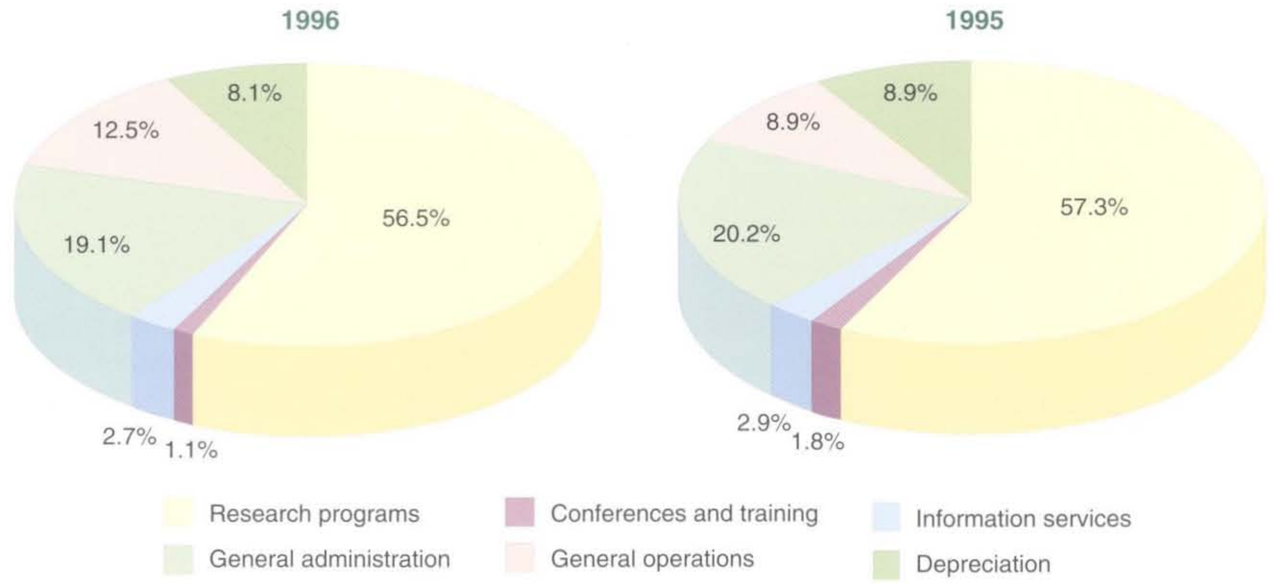
Balance sheet

	(US$ thousands) 1996	1995
Assets		
Cash and cash equivalents	9,011	7,872
Accounts receivable	7,113	11,585
Inventories	1,618	2,014
Prepaid expenses	295	298
Investments	3,000	6,000
Fixed assets - net	47,038	41,741
Other assets	781	599
Total Assets	68,856	70,109
Liabilities		
Bank overdraft	103	1,020
Accounts payable	3,136	4,382
Accruals and provosions	1,426	1,357
Payments in advance from donors	2,848	3,491
In-trust funds	8	74
Long-term liabilities	6,450	6,378
Total liabilities	13,971	16,702
Net Assets	54,885	53,407
Represented by:		
Capital invested in fixed assets	47,038	41,741
Capital Fund	7,357	12,367
Operating Fund	167	(1,022)
Special Purpose Fund	323	321

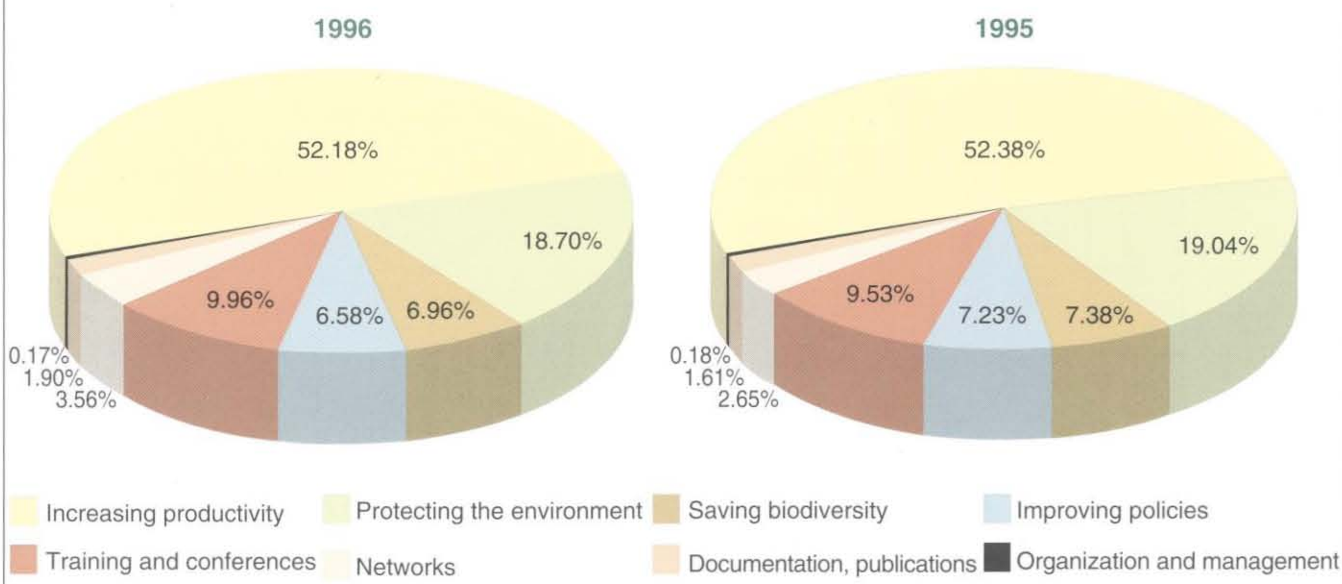
Operating results and movements on Operating and Capital Funds

	(US$ thousands) 1996	1995	Variance on 1995 increase (decrease)
(A) **Operating results**			
Revenue	30,271	30,859	(588)
Operating expenditure	32,146	30,049	2,097
Operating (deficit)/surplus before unsual items	(1,875)	810	(2,685)
Unusual items	(625)	(1,153)	528
Operating (deficit)/surplus	(2,500)	(343)	(2,157)
(B) **Operating Fund**			
Opening balance on Operating Fund-surplus/(deficit)	(1,022)	(271)	751
(Deficit)/surplus for the year	(2,500)	(343)	2,157
Transfer from Capital Fund	3,732		3,732
Previous years adjustments(net)	(43)	(408)	(365)
Closing balance on Operating Fund-surplus/(deficit)	167	(1,022)	1,189
Number of days expenditure excluding depreciation	2	(12)	
(C) **Capital Fund**			
Opening balance on Capital Fund-surplus/(deficit)	12,367	12,121	246
Depreciation charge for the year	2,718	2,723	(5)
Transfer to Operating Fund	(3,732)	229	(3,503)
Net capital additions during the year	(3,996)	(2,706)	1,290
Closing balance on Capital Fund-surplus/(deficit)	7,357	12,367	(5,010)

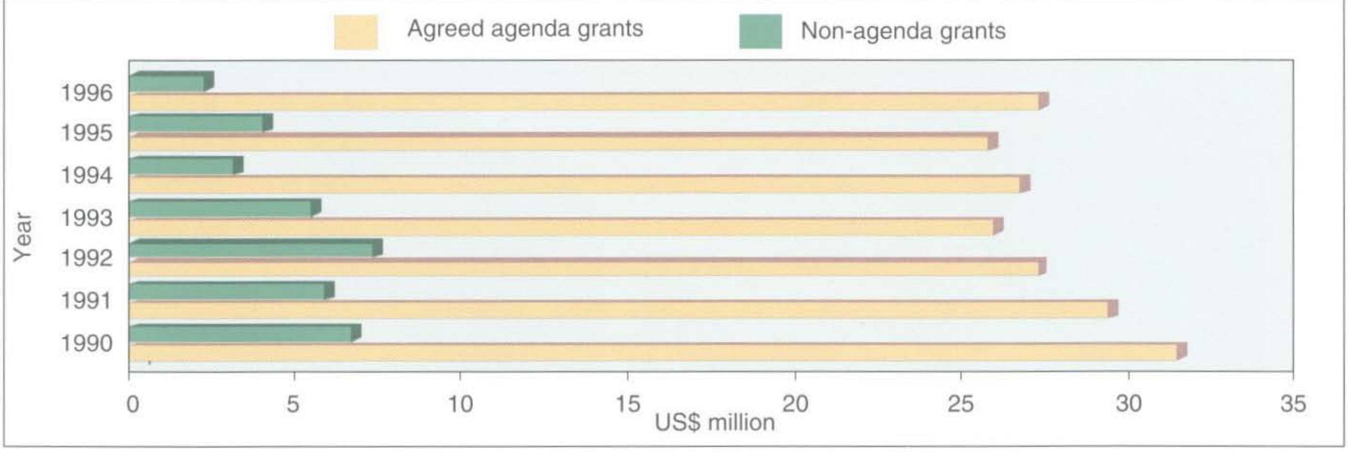
Agreed agenda and non-agenda costs by object of expenditure



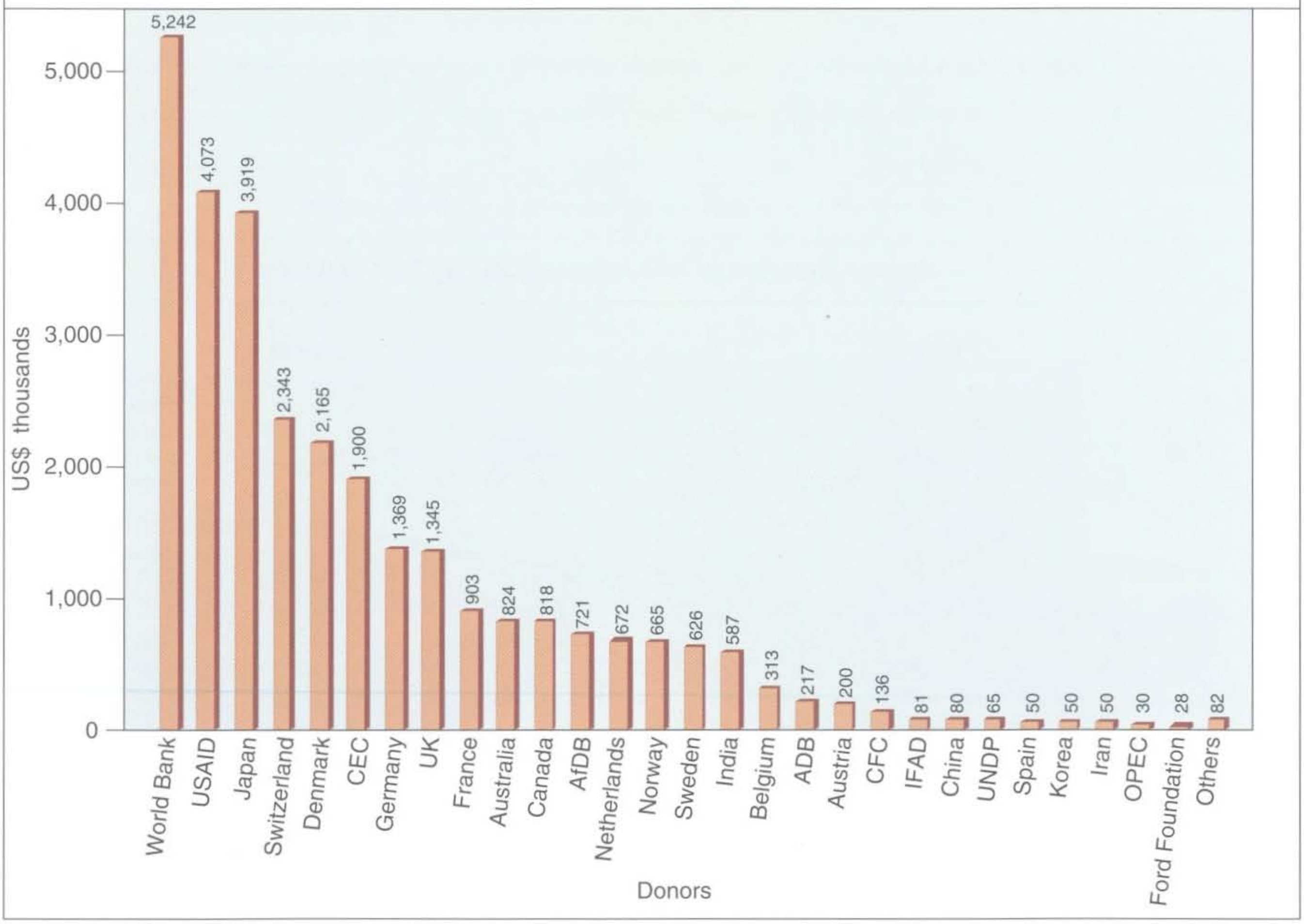
Agreed agenda and non-agenda costs by TAC activities

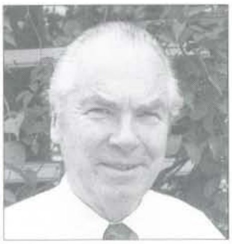


Funding trends



Agreed agenda and non-agenda donors





Hans-Jürgen von Maydell, *Germany,* **Chairman**
Hohler Weg 23
D-21465 Wentorf bei Hamburg
Germany

Pierre L Dubreuil, *France*
Centre de coopération internationale en recherche agronomique pour le developpement (CIRAD)
42 Rue Scheffer
75116 Paris
France

R S Paroda, *India,* **Vice Chairman**
Secretary, Department of Agricultural Research and Education, and Director General, Indian Council of Agricultural Research (ICAR)
Ministry of Agriculture
Government of India
Krishi Bhavan
New Delhi 110 001
India *(Host country nominee)*

Donald R Marshall, *Australia*
Head, Department of Crop Science
Faculty of Agriculture
The University of Sydney
New South Wales 2006
Australia

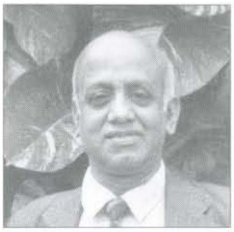
G Balakrishnan, *India*
(until Sep 1996)
Secretary to the Government of India
Ministry of Agriculture
Krishi Bhavan
New Delhi 110 001
India *(Host country nominee)*

Mamadou I Ouattara, *Niger*
Sustainable Development Advisor
United Nations Development Programme
Maison de l'Afrique
BP 11207
Niamey
Niger

Stein W Bie, *Norway*
Director
Research, Extension and Training Division
Food and Agriculture Organization of the United Nations
Via delle Terme di Caracalla
00100 Rome
Italy

José T Prisco, *Brazil*
Plant Physiology Laboratory
Department of Biochemistry and Molecular Biology
Federal University of Ceará
PO Box 1065, 60.451-970
Fortaleza, CE
Brazil

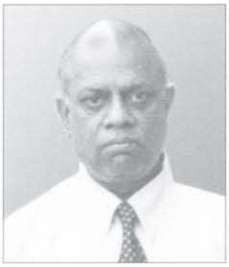
ICRISAT Governing Board 1996



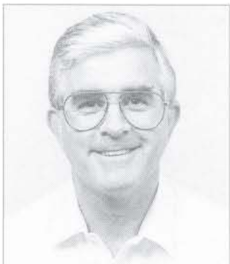
M S Rajajee, *India*
Chief Secretary to the
Government of Andhra Pradesh
Secretariat
Hyderabad 500 022
Andhra Pradesh
India *(Host country nominee)*

Mariam B Sticklen, *USA*
Associate Professor
Department of Crop and Soil
Sciences
Michigan State University
East Lansing
Michigan 48824-1311
USA

K Rajan, *India*
(from Oct 1996)
Secretary to the Government of India
Ministry of Agriculture
Krishi Bhavan
New Delhi 110 001
India *(Host country nominee)*

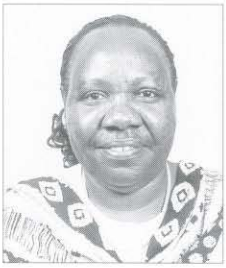


Martha B Stone, *Canada*
Senior Partner
Moenston Associates
576 Chemin Val du Lac
Val des Mont
Québec, J8N 2N5
Canada

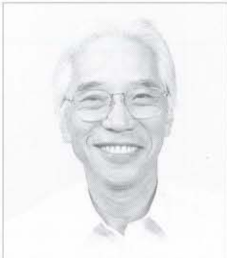


James G Ryan, *Australia*
Director General, ICRISAT
Patancheru 502 324
Andhra Pradesh
India *(Ex-officio)*

Hilda M Tadria, *Uganda*
Hilkon Technical Services
PO Box 11192
Kampala
Uganda



Ragnhild Sohlberg, *Norway*
Vice President, External Relations
and Special Projects
Human Resources Development
Norsk Hydro a.s.
Bygdoy Alle 2
N-0240 Oslo
Norway



Yoshio Tamaki, *Japan*
Professor, Faculty of Agriculture
Tohuku University,
Amamiya-machi 1-1
Tsutsumi-dohri, Aoba-ku
Sendai 981
Japan

The listings of staff working for ICRISAT on 31 December 1996 presented here indicate the staff member's name, country of origin (in italics), designation, and work location (in bold type).

Corporate

Director General's Office

James G Ryan, *Australia*, Director General, **India**

V Balasubramanian, *India*, Senior Executive Officer, **India**

Jon Jasinski, *Australia*, Special Assistant to the Director General for Educational Affairs, **India**

Waltraud R Wightman, *Germany*, Special Assistant to the Director General, **India**

Yeshwant L Nene, *India*, Deputy Director General, **India**

G J Michael, *India*, Senior Administrative Officer, India

S Parthasarathy, *India*, Assistant Director General, **India**

N P Rajasekharan, *India*, Director, Corporate Human Resources, **India**

Delhi Office

P M Menon, *India*, Manager, **India**

Rice-Wheat Consortium

Inder P Abrol, *India*, Facilitator, **India**

Desert Margins Initiative

Saidou Koala, *Burkina Faso*, Coordinator, **Niger**

CFC-Groundnut Germplasm Project

A Mayeux, *France*, Project Manager (CIRAD), **Senegal**

Associate Director Generals' Office

Don E Byth, *Australia*, Associate Director General (Research), **India**

N V N Chari, *India*, Senior Administrative Officer, **India**

Mark D Winslow, *USA*, Special Assistant to the Associate Director General (Research), **India**

Information Management and Exchange Program

R P Eaglesfield, *UK*, Program Leader, **India**

A Antonisamy, *India*, Senior Supervisor (Negative and Platemaking), **India**

Susan D Hainsworth, *UK*, Manager, Editorial Unit, **India**

T R Kapoor, *India*, Assistant Manager (Composing), **India**

Aboubacar Madougou, *Niger*, Translator/Editor, **Niger**

Esabel Maisiri, *Zimbabwe*, Information Officer, **Zimbabwe**

Eric M McGaw, *USA*, Public Awareness Officer, **India**

Savitri Mohapatra, *India*, Bilingual Editor, **India**

S Prasannalakshmi, *India*, Senior Library Officer, **India**

S Vijay Ramchander, *India*, Bilingual Editor, **India**

Upendra Ravi, *India*, Senior Production Officer (Video), **India**

S M Sinha, *India*, Manager (Art and Production), **India**

S Srinivas, *India*, Manager, (Library and Documentation Services), **India**

Ajay Varadachary, *India*, Editor, **Zimbabwe**

V Venkatesan, *India*, Senior Library Officer, **India**

Training and Fellowships Program

B Diwakar, *India*, Acting Program Leader, **India**

Djibo Y Abdoulkarim, *Niger*, Administrative Assistant, **Niger**

S K Dasgupta, *India*, Senior Training Officer, **India**

Faujdar Singh, *India*, Senior Training Officer, **India**

APSIM Modeling Support (CARMASAT)

Garry J O'Leary, *Australia*, Senior Scientist, **India**

Gayatri Devi, *India*, Senior Research Associate, **India**

Geographic Information System

Feliciano T Bantilan Jr, *Philippines*, Senior Scientist, **India**

P Mohan Rao, *India*, Scientist, **India**

Statistics

Roger D Stern, *UK*, Principal Statistician, **Niger**

Subhash Chandra, *India*, Senior Statistician, **India**

Computer Services

Suresh C Goyal, *India*, Computer Services Coordinator, **India**

S M Luthra, *India*, Manager (Systems and Operations), **India**

J Sai Prasad, *India*, Manager (Software), **India**

Donor Relations

Jugu J Abraham, *India*, Head, **India**

Finance

Kwame Akuffo-Akoto, *Ghana*, Director, **India**

S Sethuraman, *India*, Head, Financial Services, **India**

T K Srinivasan, *India*, Senior Finance Officer, **India**

Purchase

C R Krishnan, *India*, Purchase and Stores Manager, **India**

D K Mehta, *India*, Assistant Purchase and Stores Manager, **India**

Regional

Asia Region

F R Bidinger, *USA*, Executive Director (Acting), **India**

Administration

R S Aiyer, *India*, Manager, Publications Cell, **India**

C Geetha, *India*, Senior Administrative Officer, **India**

K Jagannadham, *India*, Senior Transport Officer, **India**

Samiran Mazumdar, *India*, Assistant Manager (Food Services), **India**

R G Padhye, *India*, Manager, Human Resources, **India**

Deepak M Pawar, *India*, Senior Scientific Liaison Officer, **India**

N Surya Prakash Rao, *India*, Chief Medical Officer, **India**

A Rama Murty, *India*, Senior Travel Officer, **India**

A J Rama Rao, *India*, Manager, Personnel Administration, **India**

K K Sood, *India*, Chief Security Officer, **India**

Farm and Engineering Services Program

D S Bisht, *India*, Program Leader, **India**

K Ramesh Chandra Bose, *India*, Senior Engineer (Civil), **India**

P Rama Murthy, *India*, Senior Administrative Officer, **India**

Shiva K Pal, *India*, Manager (Plant Protection), **India**

N S S Prasad, *India*, Chief Engineer (General Engineering Services), **India**

N V Subba Reddy, *India*, Assistant Manager (Landscaping), **India**

M C Ranganatha Rao, *India*, Deputy Chief Engineer (Farm Development and Construction), **India**

K Ravindranath, *India*, Manager (Farm Machinery and Mechanical Engineering Services), **India**

Marri Prabhakar Reddy, *India*, Assistant Manager (Irrigation, Labor, and Farm Maintenance), **India**

Ramesh C Sachan, *India*, Manager (Greenhouse and Controlled Environment, Training and Documentation), **India**

Plant Quarantine

A M Ghanekar, *India*, Chief Plant Quarantine Officer, **India**

Cereals and Legumes Asia Network (CLAN)

C L L Gowda, *India*, Principal Coordinator, **India**

A Ramakrishna, *India*, Scientist (Agronomy), **India**

Western and Central Africa Region

K Anand Kumar, *India*, Executive Director (Acting), **Niger**

Administration

A M B Jagne, *Gambia*, Regional Administrator, **Niger**

I M Abdou, *Niger*, Chief Electrician, **Niger**

H Amadou, *Niger*, Chief Accountant, **Niger**

S Delanne, *Niger*, Executive Assistant (Travel), **Niger**

M S Diolombi, *Niger*, Regional Finance Officer, **Niger**

Dramane Doumbia, *Mali*, Administrative Officer, **Mali**

Issa Garba, *Niger*, Manager, Purchase and Supplies, **Niger**

A Hamidou, *Niger*, Chief Security Officer, **Niger**

M Konare, *Mali*, Personnel Officer, **Mali**

Hama Kontonkomde, *Burkina Faso*, GIS Manager, **Niger**

M Mahamane, *Niger*, Senior Purchase Assistant, **Niger**

K A Moussa, *Niger*, Personnel Manager, **Niger**

G A Olaopa, *Nigeria*, Administrative Officer, **Nigeria**

H Rabe, *Niger*, Chief, Computer Services Unit, **Niger**

Farm Services

Bruno Gérard, *Belgium*, Farm Manager, **Niger**

Mory Camara, *Mali*, Farm Manager, **Mali**

West and Central Africa Sorghum Research Network (WCASRN)

I Akintayo, *Togo*, Coordinator, **Mali**

Réseau ouest et centre africain de recherche sur le mil (ROCAFREMI)

B Ouendeba, *Niger*, Coordinator, **Niger**

Southern and Eastern Africa Region

Lewis K Mughogho, *Malawi*, Executive Director, **Zimbabwe**

Administration

Christopher W Needham, *UK*, Regional Administrator, **Zimbabwe**

Colin D Chagoma, *Malawi*, Administrative Officer, **Malawi**

Peter Ndichu, *Kenya*, Accountant, **Kenya**

Irene Tapela, *Zimbabwe*, Finance Officer, **Zimbabwe**

Farm and Engineering Services Program

Nurdin S Katuli, *Tanzania*, Farm and Engineering Services Manager, **Zimbabwe**

Nathaniel Mwamuka, *Zimbabwe*, Farm Manager, **Zimbabwe**

Latin America and Caribbean Region

Don E Byth, *Australia*, Executive Director, **India**

Research Divisions

V S Swaminathan, *India*, Assistant Manager (Administration, RED Secretariat), **India**

Agronomy

Chris Johansen, *Australia*, Principal Scientist and Research Division Director, **India**

Joseph J Adu-Gyamfi, *Ghana*, Scientist, **India**

G Alagarswamy, *India*, Senior Scientist, **India**

Merle M Anders, *USA*, Principal Scientist, **India**

Y S Chauhan, *India*, Senior Scientist, **India**

S Fernandez, *Mexico*, Animal Nutritionist (ILRI), **Niger**

David J Flower, *Australia*, Principal Scientist, **India**

J Gigou, *France*, Principal Scientist (CIRAD), **Mali**

Pierre Grard, *France*, Principal Scientist (*Striga* Agronomist-CIRAD), **Mali**

Geoffrey M Heinrich, *USA*, Technology Transfer Specialist, **Zimbabwe**

P Hiernaux, *France*, Ecologist (ILRI), **Niger**

Richard B Jones, *UK*, Technology Transfer Specialist, **Kenya**

L Krishna Murthy, *India*, Senior Research Associate, **India**

V Mahalakshmi, *India*, Senior Scientist, **India**

K O Marfo, *Ghana*, Visiting Scientist, **Niger**

R C Nageswara Rao, *India*, Senior Scientist, **India**

Takuji Nakamura, *Japan*, Research Fellow (GOJ Project), **India**

H Nakano, *Japan*, Principal Scientist (Team Leader GOJ Project), **India**

Erik J van Oosterom, *Netherlands*, Research Fellow, **India**

W A Payne, *USA*, Principal Scientist, **Niger**

M V Potdar, *India*, Scientist, **India**

O P Rupela, *India*, Senior Scientist, **India**

N P Saxena, *India*, Senior Scientist, **India**

Eva Schlecht, *Germany*, Research Fellow (Animal Nutritionist-ILRI), **Niger**

S K Sharma, *India*, Assistant Manager (Field Operations), **India**

Said N Silim, *Uganda*, Principal Scientist (Crop Coordinator, Pigeonpea and Chickpea), **Kenya**

Sieglinde S Snapp, *USA*, Senior Scientist, **Malawi**

Christophe Studer, *Switzerland*, Research Fellow, **Niger**

Rima M Studer, *Germany*, Research Fellow, **Niger**

R Tabo, *Chad*, Principal Scientist, **Nigeria**

Zacharie Tchoundjeu, *Cameroon*, Agroforester (ICRAF), **Niger**

N Venkataratnam, *India*, Senior Research Associate, **India**

Cellular and Molecular Biology

Henk A van Rheenen, *Netherlands*, Principal Scientist and Research Division Director (Acting), **India**

Santosh Gurtu, *India*, Senior Research Associate, **India**

Nalini Mallikarjuna, *India*, Scientist, **India**

N Seetharama, *India*, Senior Scientist, **India**

K K Sharma, *India*, Senior Scientist, **India**

Umaid Singh, *India*, Senior Scientist, **India**

S Sivaramakrishnan, *India*, Scientist, **India**

V Subramanian, *India*, Senior Scientist, **India**

Ercole Zerbini, *Italy*, Animal Scientist (ILRI), **India**

Crop Protection

Jillian M Lenné, *Australia*, Principal Scientist and Research Division Director, **India**

A A Abbasher, *Sudan*, Research Fellow, **Niger**

O Ajayi, *Nigeria*, Principal Scientist, ICRISAT Representative in Nigeria, **Nigeria**

Ranajit Bandyopadhyay, *India*, Senior Scientist, **India**

P Delfosse, *Belgium*, Visiting Scientist, **India**

David R Butler, *UK*, Principal Scientist, **India**

B Haussmann, *Germany*, Research Fellow, **Mali**

M P Haware, *India*, Senior Scientist, **India**

Dale E Hess, *USA*, Principal Scientist, **Niger**

Stan B King, *USA*, Principal Scientist, ICRISAT Representative in Kenya (Crop Coordinator, Pearl Millet), **Kenya**

V K Mehan, *India*, Senior Scientist, **India**

A K Murthi, *India*, Senior Engineer, **India**

R A Naidu, *India*, Senior Scientist, **India**

K E Neering, *Netherlands*, Visiting Scientist, **India**

E Owusu, *Ghana*, Research Fellow, **Niger**

Suresh Pande, *India*, Scientist, **India**

G V Ranga Rao, *India*, Scientist, **India**

A Ratnadass, *France*, Principal Scientist (Entomologist-CIRAD), **Mali**

D V R Reddy, *India*, Principal Scientist, **India**

M V Reddy, *India*, Senior Scientist, **India**

Jörg Romeis, *Germany*, Visiting Scientist, **India**

S D Singh, *India*, Senior Scientist, **India**

Tom G Shanower, *USA*, Scientist, **India**

H C Sharma, *India*, Senior Scientist, **India**

S B Sharma, *India*, Senior Scientist, **India**

Pala Subrahmanyam, *India*, Principal Scientist, ICRISAT Representative in Malawi (Crop Coordinator, Groundnut), **Malawi**

R P Thakur, *India*, Senior Scientist, **India**

Vincent C Umeh, *Nigeria*, Research Fellow, **Mali**

Farid Waliyar, *France*, Principal Scientist (Crop Coordinator, Groundnut), **Mali**

John A Wightman, *New Zealand*, Principal Scientist, **India**

Ousmane Youm, *Senegal*, Principal Scientist (Crop Coordinator, Pearl Millet), **Niger**

Genetic Enhancement

John W Stenhouse, *UK*, Principal Scientist and Research Division Director, **India**

J Chantereau, *France*, Principal Scientist (Breeder-CIRAD), **Mali**

Tenson Dube, *Zimbabwe*, Senior Research Technician, **Zimbabwe**

S L Dwivedi, *India*, Senior Scientist, **India**

Doubt Gumbonzwanda, *Zimbabwe*, Senior Research Technician, **Zimbabwe**

Subhash C Gupta, *India*, Principal Scientist, **Nigeria**

C Thomas Hash Jr, *USA*, Principal Scientist (Crop Coordinator, Pearl Millet), **India**

K C Jain, *India*, Senior Scientist, **India**

Jagdish Kumar, *India*, Senior Scientist, **India**

Murairo Madzvamuse, *Zimbabwe*, Senior Research Technician, **Zimbabwe**

Debbie Martin, *Zimbabwe*, Senior Research Technician, **Zimbabwe**

Emmanuel S Monyo, *Tanzania*, Senior Scientist, **Zimbabwe**

Sanders Mpofu, *Zimbabwe*, Senior Research Technician, **Zimbabwe**

Samwiri Z Mukuru, *Uganda*, Principal Scientist (Crop Coordinator, Finger Millet), **Kenya**

D S Murty, *India*, Principal Scientist (Crop Coordinator, Sorghum), **Mali**

Shyam N Nigam, *India*, Principal Scientist (Crop Coordinator, Groundnut), **India**

B R Ntare, *Uganda*, Principal Scientist (Crop Coordinator, Groundnut), **Nigeria**

A Babatunde Obilana, *Nigeria*, Principal Scientist (Crop Coordinator, Sorghum), **Zimbabwe**

S Ouattara, *Côte d'Ivoire*, Research Fellow, **Niger**

K N Rai, *India*, Senior Scientist, **India**

H Frederick W Rattunde, *USA*, Scientist, **India**

Belum V S Reddy, *India*, Senior Scientist, **India**

L J Reddy, *India*, Senior Scientist, **India**

J F Renno, *France*, Principal Scientist (Geneticist-ORSTOM), **Niger**

K B Saxena, *India*, Senior Scientist, **Sri Lanka**

Laxman Singh, *India*, Principal Scientist (Crop Coordinator, Pigeonpea), **India**

Onkar Singh, *India*, Senior Scientist, **India**

S C Sethi, *India*, Senior Scientist, **India**

B S Talukdar, *India*, Scientist, **India**

Pieter J A van der Merwe, *South Africa*, Principal Scientist, **Malawi**

H D Upadhyaya, *India*, Scientist, **India**

Eva Weltzien Rattunde, *Germany*, Senior Scientist, **India**

Genetic Resources

Paula Bramel-Cox, *USA*, Principal Scientist and Research Division Director, **India**

K E Prasada Rao, *India*, Visiting Scientist, **India**

R P S Pundir, *India*, Senior Scientist, **India**

P Remanandan, *India*, Senior Scientist, **India**

A K Singh, *India*, Senior Scientist, **India**

Cécile Grenier, *France*, Special Project Scientist (CIRAD), **India**

Socioeconomics and Policy

David D Rohrbach, *USA*, Principal Scientist and Research Division Director, **Zimbabwe**

Mohammed M Ahmed, *Sudan*, Research Fellow, **Zimbabwe**

J Baidu-Forson, *Ghana*, Principal Scientist, **Niger**

Ma Cynthia S Bantilan, *Philippines*, Principal Scientist, **India**

Duncan H Boughton, *UK*, Senior Scientist, **Malawi**

Peter G Cox, *Australia*, Principal Scientist, **India**

S K Debrah, *Ghana*, Principal Scientist, ICRISAT Representative in Mali, **Mali**

Laeticia Ewong, *Cameroon*, Visiting Scientist, **Mali**

H Ade Freeman, *Sierra Leone*, Senior Scientist, **Kenya**

P K Joshi, *India*, Senior Scientist, **India**

Timothy G Kelley, *USA*, Principal Scientist, **India**

Shashi Kolavalli, *USA*, Principal Scientist, **India**

K G Kshirsagar, *India*, Senior Research Associate, **India**

Killian Mutior, *Zimbabwe*, Research Associate, **Zimbabwe**

J Ndjeunga, *Cameroon*, Research Fellow (Economics), **Niger**

P Parthasarathy Rao, *India*, Senior Research Associate, **India**

K V Subba Rao, *India*, Senior Research Associate, **India**

T O Williams, *Nigeria*, Economist (ILRI), **Niger**

Atse Yapi, *Ghana*, Research Fellow, **Mali**

Soils and Agroclimatology

R J K Myers, *Australia*, Principal Scientist and Research Division Director, **India**

N K Awadhwal, *India*, Senior Scientist, **India**

A Bationo, *Burkina Faso*, Principal Scientist (IFDC), **Niger**

C Bielders, *Netherlands*, Scientist, **Niger**

A C Buerkert, *Germany*, Coordinator, ROTAPHOS, **Niger**

Niek van Duivenbooden, *Netherlands*, Senior Scientist, **Niger**

M C Klaij, *Netherlands*, Principal Scientist, **Ethiopia**

J V D K Kumar Rao, *India*, Senior Scientist, **India**

Kofi B Laryea, *Ghana*, Principal Scientist, **India**

Keuk-Ki Lee, *Korea*, Principal Scientist, **India**

F Mahler, *Germany*, Agronomist, (University of Hohenheim), **Niger**

Prabhakar Pathak, *India*, Senior Scientist, **India**

K P C Rao, *India*, Scientist, **India**

T J Rego, *India*, Senior Scientist, **India**

Björn Seeling, *Germany*, Research Fellow, **India**

Piara Singh, *India*, Senior Scientist, **India**

S Uchida, *Japan*, Visiting Scientist, **Japan**

S M Virmani, *India*, Principal Scientist, **India**

S P Wani, *India*, Senior Scientist, **India**

ICRISAT won the **King Baudouin Award** of the CGIAR for 1996, in recognition of its outstanding achievement in the development of disease-resistant, yield-increasing pearl millet in collaboration with advanced research institutions and national research programs.

The Kano State Government, Nigeria, awarded a Certificate of Commendation to **ICRISAT**, in recognition of the Institute's "immense contribution towards promoting community development programmes in Kano State."

The **ICRISAT research team** in Nigeria received an award from the Women Farmers' Association of Nigeria in recognition of its "immense contribution to the development of agriculture in Nigeria".

An ICRISAT **poster** entitled "Effect of temperature and leaf wetness periods on infection of sorghum by *Colletotrichum graminicola*" won the Best Poster Award at the 48th Annual Meeting of the Indian Phytopathological Society. The poster was presented by Y D Narayana, and coauthored by R Bandyopadhyay, D R Butler, R K Reddy, and J M Lenné, Crop Protection Division.

ICRISAT's **video** on IPM "To spray or not to spray" won second prize out of 19 entries at the fourth annual National Video Festival organized by the Public Relations Society of India.

Deepak Jadhav was awarded a Rothamsted International Fellowship to undertake collaborative research on insecticide resistance for 6 months with the Biological and Ecological Chemistry Department of Rothamsted, UK.

J M Lenné received the degree of Doctor of Agricultural Science (DAgSc) from the University of Melbourne, Australia, for her distinguished contributions to agricultural science.

In recognition of his outstanding accomplishments and contributions in the field of genetic resources, **Melak H Mengesha**, former Director, Genetic Resources Division, was selected for the Distinguished Alumni Award by the School of Agriculture at Purdue University, USA.

Kanayo F Nwanze was appointed **Director General** of the West African Rice Development Association (**WARDA**).

S B Sharma was co-winner of the Chairman's Excellence in Science Award of the CGIAR, in the category 'Outstanding Local Professional,' in recognition of his research at ICRISAT on parasitic nematodes affecting the production of pigeonpea, chickpea, and groundnut.

Sheila Vijayakumar was invited to become a Fellow of the Indian Phytopathological Society.

S M Virmani was invited by the Government of India to be a member of the Planning Commission Working Group on Rainfed/Dryland Agricultural Production.

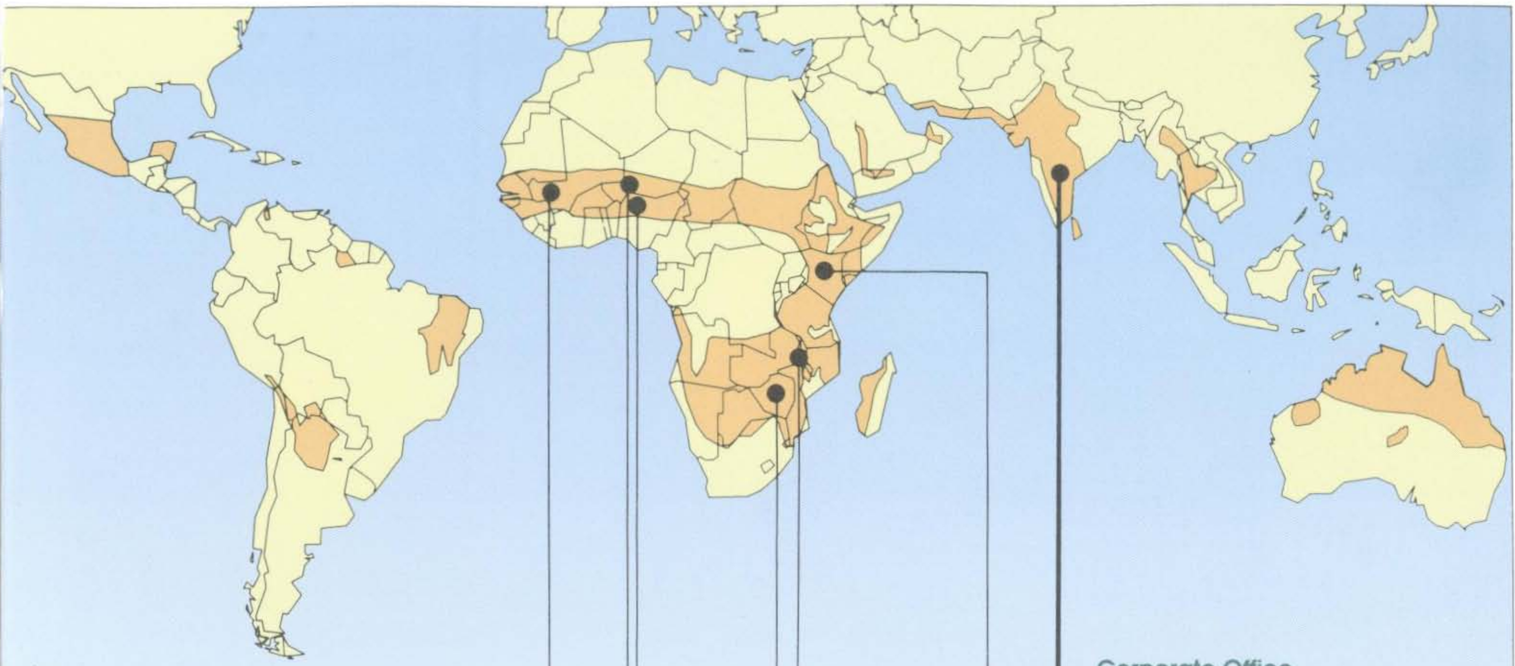
Varsha Wesley, former Visiting Scientist, was selected for the 1996 Jawaharlal Nehru Award for her thesis on peanut clump virus.

The ICRISAT Southern and Eastern Africa Region Annual Report 1995 won the **1997 ACE Critique Gold Award** of the Agricultural Communicators in Education (ACE), USA, in the 'Four-color special report' category. It was selected from 474 entries, in a worldwide contest for publication editing, design, and production held each year.

Three ICRISAT public awareness documents in the 'Food from Thought' series (No 2. Making a difference – chickpea in the Barind; No 3. Improving the unimprovable – succeeding with pearl millet; and No 4. The seeds they prayed for) won the **1997 ACE Critique Silver Award**.

ADB	Asian Development Bank (Philippines)
AfDB	African Development Bank (Côte d'Ivoire)
AME	Agriculture Man Ecology (India)
ANGRAU	Acharya N G Ranga Agricultural University; formerly Andhra Pradesh Agricultural University, APAU (India)
BBM	broadbed maker
BMZ	Bundesministerium für Wirtschaftliche und Entwicklung Zusammenarbeit (Germany)
CCER	Center-Commissioned External Review
CEC	Commission of the European Communities (Belgium)
CFC	Common Fund for Commodities (Netherlands)
CGIAR	Consultative Group on International Agricultural Research (USA)
CIAT	Centro Internacional de Agricultura Tropical (Colombia)
CIMMYT	Centro Internacional de Mejoramiento de Maïz y Trigo (Mexico)
CIRAD	Centre de coopération internationale en recherche agronomique pour le développement (France)
CLAN	Cereals and Legumes Asia Network (ICRISAT, India)
CRIDA	Central Research Institute for Dryland Agriculture (India)
DDS	Deccan Development Society (India)
EMS	ethyl methane sufonate
EPMR	External Program and Management Review
EU	European Union (Belgium)
FAO	Food and Agriculture Organization of the United Nations (Italy)
GIS	geographic information system
GOJ	Government of Japan
GPS	global positioning system
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit (Germany)
IAC	ICRISAT Asia Center (India)
IADB	Inter-American Development Bank (USA)
IAR	Institute of Agricultural Research (Ethiopia)
IAR	Institute of Agricultural Research (Nigeria)
ICAR	Indian Council of Agricultural Research
ICRAF	International Centre for Research in Agroforestry (Kenya)
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics (India)
IER	Institut d'économie rurale (Mali)
IFAD	International Fund for Agricultural Development (Italy)
IFDC	International Fertilizer Development Center (USA)

IITA	International Institute of Tropical Agriculture (Nigeria)
ILRI	International Livestock Research Institute (Ethiopia and Kenya)
INTSORMIL	USAID Title XII International Sorghum/Millet Collaborative Research Support Program (USA)
IPGRI	International Plant Genetic Resources Institute (Italy)
IPM	integrated pest management
ISC	ICRISAT Sahelian Center (Niger)
JVP	Joint Vertisols Project (Ethiopia)
KARI	Kenya Agricultural Research Institute
KNARDA	Kano State Agricultural and Rural Development Authority (Nigeria)
LCRI	Lake Chad Research Institute (Nigeria)
MTM	Mid-Term Meeting (CGIAR)
MTP	Medium-Term Plan
MYRADA	Mysore Resettlement and Development Agency (India)
NARS	national agricultural research systems
NGO	non-governmental organization
NPV	nuclear polyhedrosis virus
NRI	Natural Resources Institute (UK)
ONDR	Office nationale du développement rural (Chad)
OPEC	Organization of Petroleum Exporting Countries (Austria)
ORSTOM	Institut français de recherche scientifique pour le développement en coopération (France)
PDA	potato dextrose agar
ROCAFREMI	Réseau ouest et centre africain de recherche sur le mil (ICRISAT, Niger)
SADC	Southern African Development Community (Botswana)
SAT	semi-arid tropics
SEA	Southern and Eastern Africa
SMIP	Sorghum and Millet Improvement Program (SADC/ICRISAT, Zimbabwe)
SSP	single superphosphate
TAC	Technical Advisory Committee (CGIAR)
UNDP	United Nations Development Programme (USA)
UNICEF	United Nations Children's Fund (USA)
USAID	United States Agency for International Development
WBAS	weather-based advisory scheme
WCA	Western and Central Africa
WCASRN	West and Central Africa Sorghum Research Network (ICRISAT, Mali)
WVI	World Vision International (USA and Switzerland)



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