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International Crops Research Institute for the Semi-Arid Tropics

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Preface

Research highlights covering 1998-99 were summarized in Volume 1 of the Socioeconomics and Policy Program Annual Report 1998-99. This volume provides additional information on SEPP activities. Progress is reported separately for each relevant milestone of the five projects S1 to S5.

S1: Identifying opportunities for improving the impact of ICRISAT research

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Project goal

Identify opportunities to improve the research impact of ICRISAT towards achieving the CGIAR goals of alleviating poverty (especially for women), sustainable food security, and protection of natural resources.

Project intermediate goal

Undertake *ex-ante* and *ex-post* analysis in partnership with national programs to guide ICRISAT-NARS future research directions and impact.

Project purpose

Impact assessment is a critical component of the total research cycle. It provides researchers with valuable lessons on the relevance and appropriateness of their efforts, and guides a redirection of those efforts where needed. It also provides stakeholders with objective documentation of the outcomes of their investments of time, effort, and resources, which are necessary for sustaining those inputs. Impacts will be assessed in terms of achieving the over-arching CGIAR goals of alleviating poverty, improving the sustainability of natural resources, and improving food security, including careful attention to gender-related issues such as malnutrition of women in the household, task drudgery, gainful employment, and others.

Outputs

Details are provided in the following pages, under six headings:

- 1.1 Joint research impact assessments: completed assessments released through publications, conference papers and workshop proceedings
- 1.2 Adoption case studies providing objective documentation of the uptake of ICRISAT/NARS research investments
- 1.3 Socioeconomic and institutional constraints to the adoption of Vertisol technology identified
- 1.4 On-the-job and summer training programs
- 1.5 Training modules for research evaluation and impact assessment methods
- 1.6 Integrated impact database

1.1 Joint research impact assessments: completed assessments released through publications, conference papers and workshop proceedings

1.1.1 Spillover Impacts of Sorghum Germplasm Research

by U.K. Deb, M.C.S. Bantilan, B.V.S. Reddy, A.B. Obilana, P.B. Cox, N.K. Rao

Background

Technology spillover effect refers to a situation where a technology developed for one crop at a specific location can be adapted to improve the production efficiency of the same crop at other locations. However, the degree of applicability may vary across location due to the differences in production environments—agronomic, climatic, and ecological factors. Technology spillover effect is also known as across-location spillover effect and across-environment spillover effect. One example of technology spillover impact is, ICRISAT developed sorghum variety ICSV 112 (SPV 475). This variety was primarily intended for India, but was released in India (CSV 13), Mexico (UNAL 1-87), Nicaragua (Pinoleso), Zimbabwe (SV1). This variety yield 3.4 t ha⁻¹ at Patancheru (India) and matures in 115-120 days (ICRISAT 1990). The objective of this paper is to quantify the spillover impacts of sorghum genetic enhancement research at ICRISAT.

Methodology

Multilocation trial data from two different sources were analyzed: International Sorghum Varietal and Hybrid Adaptation Trial (ISVHAT), and All India Coordinated Sorghum Improvement Project (AICSIP). Research domains for ICRISAT research on sorghum genetic enhancement earlier identified by sorghum scientists is used as a point of reference in delineating spillover effects across different environments which may correspond to varying agro-ecological characteristics, constraints and research opportunities. These research domains are presented Table 1.

For estimation purposes, the performance of a variety is assumed to be a function of environmental and time variables (e.g. location, year) as well as technology variables (e.g. vintage of the variety, origin of the variety). Technology variables were included to represent characteristics of varietal technology. The following regression model was used to estimate the spillover matrix

$$Y_{hgt}^j = a + b_h DLOC_h + c_t DYEAR_t + v VINT + w_i DORIG_i + r MR + \epsilon_{hgt}$$

for $j=1,2,\dots,n$ (1)

where j is the test domain in which the yield data point is observed, Y_{hgt}^j is the observed yield (kg per ha) of the g th entry at the h th trial location in the environment j and t th trial year, $DLOC_h$ is a vector of dummy variables equal to one if data point belongs to location h , zero otherwise; $DYEAR_t$ is a vector of dummy variables equal to one if data point belongs to year t , zero otherwise; $VINT$ is a variable to reflect the age of vintage of a variety approximated by the trial year in which the g th variety first

appeared; $DORIG_i$ is a vector of dummy variables equal to one if i th variety belongs to the origin group i , zero otherwise; MR is the inverse Mill's ratio; and ϵ is the error term.

The model was estimated separately for each sorghum domain. The coefficient for $DORIG$ represented the performance of varieties of different environmental origins in a given sorghum domain relative to the “home varieties”. The varietal group originating from the test domain were considered as the benchmark variable (i.e. dummy variable $DORIG_j$ were dropped from the equation for each domain). Therefore, the coefficients of $DORIG_i$ are the differential yields defined as ($w_{ji} = Y_{ij} - Y_{jj}$). These coefficients were used to estimate Y_{ij}/Y_{jj} to give the elements of the spillover matrix, c_{ij} , based on the constant Y_{jj} (approximated by the arithmetic mean) for each domain.

Results and Discussion

Technology spillover impacts. The estimated spillover coefficients are presented in Table 2 in terms of percentage coefficients based on average yields of the benchmark variables (i.e., $c_{ij} = Y_{ij}/Y_{jj}$). Off-diagonal values less than one indicate that directly introduced sorghum cultivars from other domains yield less than those developed by local breeding programs in the test domain. Similarly, values greater than one (as in the case of ICRISAT-Patancheru bred cultivars) indicate that directly introduced cultivars from these sources yield more than those developed by local breeding programs in the test domain.

The significant yield advantages expressed by varieties developed and evaluated in SD7 and SD8.1 (implying less direct spill-ins of cultivars developed for other domains) can be explained by the fact that sorghum cultivars bred for rainfed environments cannot perform better in irrigated environments. The ‘environmental distance’ also contributes to the significant yield advantage enjoyed by domestic cultivars in SD7 (irrigated) and SD8.1 (high latitude) domains. The poorer performance of cultivars bred for wide adaptability by ICRISAT-Patancheru in locations like SD8.1 (e.g. China) can be explained by the fact that China, with a strong research capacity and long experience in sorghum research, has developed improved materials more suitable to their specific environment. Then, the best way for an international research organization like ICRISAT to assist China is to provide intermediate products (like enhanced germplasm materials) rather than finished products (varieties/ hybrids). This argument is strengthened by results as shown in the next section that out of 10 hybrids developed in China after 1987, seven are based on ICRISAT germplasm materials. A direct policy implication for ICRISAT is that it should conduct upstream (strategic) breeding research to provide more benefit to NARS with strong research facilities. ICRISAT sorghum researchers initiated a move in this direction in 1995.

Sorghum cultivars developed for irrigated environments (SD7) showed 13% grain yield advantage in SD2 (late maturing dual purpose sorghum) but not vice versa. The asymmetry of these two domains explains the asymmetry in the spillover matrix (i.e. $c_{ij} \neq c_{ji}$). However, without comparing for fodder yield we should not say that sorghums bred for irrigated environments actually perform better in SD7 than in SD2. The major breeding target for dual purpose sorghum (SD2) is to provide high yields of both grain and

fodder; while the major target for irrigated sorghum is to increase grain yield alone. It should then be expected that cultivars bred for SD7 environments may provide higher grain yield but not necessarily higher stalk yield.

Examining the performance of ICRISAT-Patancheru bred cultivars across sorghum domains, a prominent result of the regression analyses is the wide adaptability and transferability of ICRISAT cultivars across different domains. The environmental specificity and associated selective environmental heterogeneity evident in the comparison of NARS cultivars are not observed in the comparison among ICRISAT cultivars across different sorghum domains. This points to the success of international research systems in reducing GxE interactions. The experience of ICRISAT in developing widely adapted cultivars especially in a range of rainfed environments and in low altitude areas has shown that these improved cultivars now account a significant share of area of sorghum growing developing countries.

The results above are based on analysis of the global ISVHAT data. The same analysis was conducted using data from the All-India coordinated sorghum improvement (AICSIP) trials data. The same model represented by Equation (1) was estimated and the results of the analysis are presented in Table 3. The spillover coefficients are presented in terms of percentage coefficients based on average yields of the benchmark variables (i.e., $c_{ij} = Y_{ij}/Y_{jj}$). Off-diagonal values less than one indicate that directly introduced sorghum cultivars from other sorghum domains yield less than those developed by local breeding programs in the test domain. Similarly, values greater than one indicate that directly introduced sorghum cultivars from these sources yield more than those developed by local breeding programs in the test domain. The similar results obtained from the AICSIP and ISVHAT data sets indicate the success of the collaboration between ICRISAT and Indian NARS in terms of reducing GxE interactions and developing widely adaptive cultivars in India.

Determinants of technology spillover. This component of the study examined research capacity as a factor influencing the extent of technology spillovers. Data was collected on the strength of different NARS in terms of scientific capability in sorghum research measured through the number of scientists and their formal education levels. India and China had the strongest research capabilities in Asia among developing countries growing sorghum. They have large scientific mass (China 200 scientists and India about 200 scientists) engaged in sorghum research. Other countries have a limited number of scientists ranging from 3 (in Rwanda) to 50 (in Ethiopia). Number and level of formal education of sorghum breeders in a country were used to indicate the capability of the country to generate new technology while the number of agronomists, seed technologists, entomologists, pathologists and social scientists indicate the strength in adaptive research. Countries with a large number of scientists in their breeding programs are expected to release more cultivars from their own crosses. Countries with strong research capacity are also expected to utilize a large number of breeding materials from international research centers like ICRISAT. Utilization is measured by determining the pedigree of the released cultivars.

For countries with less number of breeders but more capacity for adaptive research, it is expected that there is a larger share of released cultivars from international sources after adaptive trials. The number of

released cultivars directly from ICRISAT are expected to be more in the countries with weak research capability compared to the countries with strong research capability.

Table 1. Sorghum research domains.

Domain	Production system characteristics	Major constraints	Locations
SD I (Wide adaptability)	Rainy season, multi-purpose grain, stalk, fodder (fodder emphasis). Wide adaptability (June-August sowing).	Grain mold, shoot fly, headbug	W Africa (southern tier), India (Tamil Nadu, S Karnataka, Andhra Pradesh).
SD II (Dual purpose, specific adaptability)	Rainy season, dual purpose (grain and fodder). Specific adaptation (June sowing). Medium to late maturing types.	Stem borer, grain mold, midge, shoot fly, drought	E and S Africa, India (Andhra Pradesh, N Karnataka, Maharashtra, Madhya Pradesh, Gujarat), Latin America (some areas).
SD III (Dual purpose, fodder emphasis)	Rainy season, dual purpose (fodder emphasis). Early maturing.	Shoot fly, stem borer	W Africa (northern tier), E Africa (Yemen, Somalia), India (E Rajasthan), Latin America (some areas), China, Iran.
SD IV (Forage sorghum)	Rainy season, forage types (thin stalk, tillering), late-maturing.	Stem borer, leaf diseases	India (N gangetic plain), Pakistan.
SD V (Early sowing rabi)	Postrainy season (early sown, before Oct). Bold grain types, dual purpose.	Shootfly, stalk rot, head bugs	India (S Andhra Pradesh, S Karnataka).
SD VI (Late sowing rabi)	Postrainy season (late sown, mid/late Oct). Bold grain, require temperature-insensitive cultivars.		India (Gujarat, S Maharashtra, N Karnataka).
SD VII (Irrigated)	Irrigated sorghum		Iran, Egypt, Wad Medani (Sudan)
SD VIII (Extreme altitude)	Others		(i) High altitude: China (ii) Low latitude: Indonesia, Brazil, Ecuador, Venezuela

Conclusions

The results of data analysis showed that ICRISAT derived cultivars generally performed better than NARS derived cultivars. The extent of technology spillover from finished product is negatively related to the research capability of NARS. The likelihood of technology spillover and research capability of the NARS are found to be inversely related. The study suggests separate breeding strategies should be followed by ICRISAT for strong and weak NARS.

Table 2. Estimated spillover matrix for sorghum improvement research at the global sorghum domain level computed from ISVHAT trials data, 1989-92).

Origin of cultivar	Sorghum domain where cultivars were tested						
	SD1	SD2	SD3	SD4	SD7	SD8.1	SD8.2
SD1	1.00	0.95	0.84	1.50	0.73	0.36	1.16
SD2	0.96	1.00	0.87	1.88	0.78	0.23	1.28
SD3	0.88	1.05	1.00	1.68	0.85	0.42	1.21
SD4				1.00			
SD7	0.80	1.13	0.80	1.28	1.00		
SD8.1						1.00	
SD8.2							1.00
ICRISAT-Patancheru	1.15	1.13	1.07	2.17	0.83	0.33	1.27

Table 3. Estimated spillover matrix for sorghum improvement research at the sorghum domain level (computed from AICSIP trials data, 1975-96).

Origin of cultivar	Sorghum domain where cultivars were tested							
	SD1	SD2	SD3	SD4	SD5	SD6	SD7	Outside
SD1	1.00	1.08			1.08	1.12		
SD2	0.94	1.00			1.09	1.65		
SD5	0.84	0.86			1.00	0.97		
SD6		1.00			0.92	1.00		
ICRISAT-derived	1.08	1.11			1.23	1.12		

1.1.2 Impact of ICRISAT Research on Australian Agriculture

By M.C.S. Bantilan, J. Brennan, B.V.S. Reddy, and Chris Johansen

Background

A study was conducted to investigate and document the impact of ICRISAT research on Australian agriculture. The study was jointly completed by the Socioeconomics and Policy Program and New South Wales Agriculture of Australia and funded by the Australian Centre for International Agricultural Research (ACIAR). The study aims to:

- a) Enable ICRISAT to understand better the role of its germplasm products in varietal development;
- b) Identify the constraints and limitations of ICRISAT products and germplasm lines for Australian conditions and whether there has been any flow of Australian material back to ICRISAT;
- c) Provide a basis for assessing whether other types of research outputs from ICRISAT are applicable to developed countries such as Australia: and
- d) Identify any implications for Australia's investment in ICRISAT through foreign aid payments.

The main emphasis in this study was on (b), (c) and (d). Identification and assessment of those impacts on Australia will enable the first objective to be met by allowing ICRISAT to understand better the role of its different outputs in one developed country.

Methodology

The first task in the analysis was to identify the links between ICRISAT and the relevant Australian research programs for each of the mandate crops. The linkages differed for each crop, but there was good collaboration between the Australian programs and their ICRISAT counterparts. There was regular exchange between Australia and ICRISAT, and several Australians work at ICRISAT or have worked there in the past. In addition, a number of ICRISAT researchers have spent time visiting and working in Australia.

A large amount of ICRISAT material either has been used in the past or is being used at present in Australian breeding programs. In addition, there had been some direct acquisitions and releases in Australia of Indian varieties, often made available via the ICRISAT germplasm exchange distribution system. However, despite these strong linkages, there was little evidence of direct impact of ICRISAT research on Australian production to date. There appeared to be few varieties or hybrids in any of the crops that were being grown commercially based on ICRISAT germplasm, although some of the crops, particularly sorghum and chickpea, had ICRISAT material with particular desirable characteristics in the advanced lines in the breeding programs. Therefore, while it is likely that there will be future impacts, as some of these lines are released by breeder and grown by Australian farmers, there has been no direct impact on farms to date. The analysis, then, relied on being able to project future benefits for some of the crops.

Economic surplus analysis was used in the study to quantify these future benefits to be derived for producers and consumers of sorghum and chickpea in Australia. It may be mentioned here that though there were relatively strong links with ICRISAT for several of the mandate crops, only in sorghum and

chickpeas were there both strong links and a substantial Australian industry to provide the necessary conditions for a significant benefit flowing back to Australia. For example, there had been an especially strong relationship in pigeonpeas, with ICRISAT materials being closely tested in Australia, and with a strong personal connection between the Australian and ICRISAT researchers. However, there is no significant pigeonpea industry in Australia, so that the strong research links were not translated into significant monetary benefits to Australia. On the other hand, for groundnut/peanut, while there is a small but significant industry in Australia, there has been no identifiable impact of ICRISAT material on the Australian program or the varieties being grown. A similar situation applied to millets, as there is minor production of millet in Australia, but no evidence that there had been any direct impact from ICRISAT on the materials being grown.

In addition, a significant part of resource management research at ICRISAT, such as physiological modelling, has relevance to Australia. However, it was not possible in this report to put an economic value on those areas of collaborative research.

As a result, the empirical analysis was restricted to the impact on sorghum and chickpea production. For the other crops the size of any benefits identified would have been insignificant at this time. It is, of course, possible that in the future there will be some important identifiable impacts for the other mandate crops or from resource management research.

Results and Discussion

For sorghum, the most significant contribution from ICRISAT to Australian agriculture has been introduction of improved midge resistance combined with desirable white grain and tan plant color through material such as ICSV 745 and PM 13654. There are several advanced breeding lines that have the resistance and combination of characteristics incorporated from ICRISAT-derived material in them. As a result, industry experts expect that hybrids with this resistance will be available to the growers in the near future, and that the resistance of such material will have a significant economic impact on the sorghum industry. On the basis that such resistance is likely to increase yield by 5% in the 50% of the crop affected by midge each year, the expected gains to Australia in terms of yield are estimated at 2.5%. That translates to a cost reduction of \$4.02 per ton, or an annual cost saving of \$4.69 million at recent average production levels.

For chickpeas, the impact of ICRISAT research is likely to be different in Western Australia (WA) from the rest of Australia. As a result, the WA impact is assessed separately in this analysis. In WA, two ICRISAT varieties, Heera and Sona, were released in July 1997. They are seen as having a significant impact on the chickpea industry in WA. They have significant levels of cold tolerance, and are expected to yield an average of 10% higher than alternative varieties that will be available over the next 5 years. At the same time, the area of chickpeas in WA is estimated to double to 100,000 ha by 2002. In the other States, there are no such clearly identifiable benefits from the use of ICRISAT's chickpea materials. However, material either developed from or incorporating ICRISAT background is prevalent throughout the breeding materials currently in use in Australia, and a weighted average of 42% of the breeding materials have ICRISAT background. On the basis of these figures, the future gains from improved

chickpea varieties in the other States will have a strong impact from ICRISAT material. It is estimated that ICRISAT will contribute 2.1% of the expected 5.0% yield growth in the five years to 2002. That is equivalent to a cost reduction of \$39.18 per ton for WA and \$8.78 per ton for the rest of Australia, or an annual cost saving of \$5.21 million for Australia at the expected production levels.

The economic analysis also assesses the impact on Australia of ICRISAT's research in the rest of the world, via an impact on prices. To the extent that ICRISAT's research in the rest of the world has increased production, there will be a downward impact on price. Given finite supply and demand elasticities, any increase in production will mean a decline in price for the traded goods sector. Work at ICRISAT has led to development of estimates of the likely impact in future of ICRISAT's research. The increases in the world's production of chickpeas and sorghum are likely to have a downward impact on prices for the predominantly export-oriented sorghum and chickpeas industries in Australia.

On that basis, the Australian industry faced lower prices as a result of ICRISAT's research, at the same time as they were experiencing yield gains. The economic analysis of those spillover impacts in an economic welfare framework revealed that the overall net effect for Australia was a reduction in benefits gained by producers. Australian sorghum producers will lose more through the lower prices than the benefits they gain from the higher yields, resulting in an overall loss of \$0.55 million per year. For chickpeas, Australian producers will also lose more from the price fall than they will gain from higher yields, with a resultant loss of \$0.81 million per year. Overall, sorghum and chickpea producers will lose an average of \$1.36 million per year. These losses occur because Australian producers are unable to make use of the productivity gains from ICRISAT research to the same extent as producers in the rest of the world, and hence cost reductions gained by other producers are larger than those gained by Australian producers. It should be noted that Australian producers are enjoying productivity gains from domestic research programs unrelated to ICRISAT that have not been considered in this project. No attempt has been made to assess whether Australian producers are becoming more or less efficient than producers in the rest of the world.

On the other hand, Australian consumers of those grains (that is, primarily the livestock sector) will make significant gains. Sorghum consumers will gain an average of \$1.69 million per year, while for chickpeas the gains will average \$1.19 million per year.

Overall, the net gain to Australia as a result of the research effort at ICRISAT averages \$1.28 million per year, or an aggregate of \$30.8 million (in 1996 dollars) over the period to 2022 (Table 1). Approximately three-quarters of those gains are achieved in the sorghum industry, and one-quarter for chickpeas.

Conclusions

This study has produced significant findings at two levels. The first level has been the identification of anticipated spillover benefits in terms of cost reduction for producers in two of the ICRISAT mandate crops, namely sorghum and chickpeas. Those cost reductions are expected to result from yield increases attributable to germplasm developed at ICRISAT or collected by passing through ICRISAT and incorporated into genotypes that will be grown in Australia.

Table 1. Summary of benefits to Australia from ICRISAT research.

Crop	Aggregate benefit, 1999-2022^a (\$ million)	Average annual benefit (\$ million)
Sorghum	27.3	1.14
Chickpeas	9.1	0.38
Total	36.4	1.52

a: In 1996 Australian dollars, discounted at 8% per annum.

The second level at which significant findings have emerged for the first time is in the incorporation of the price effects of international agricultural research for those crops. In these two industries, the price effects resulting from successful ICRISAT research were found to be significant. The lower prices for sorghum and chickpeas led to significant income reductions for Australian producers, and these were only partly offset by the increased yields. The gains for the Australian consumers of these grains (that is, the Australian livestock sector) from the lower prices were less than the losses from price effects for Australian producers, because the significance of exports meant that overseas consumers received many of the consumer benefits. Thus producers have incurred losses from the price effects because they have been unable to capture the benefits of ICRISAT research to the same extent as producers in the rest of the world.

These findings have some important implications for Australian agriculture:

- a) International Centres such as ICRISAT remains a source of materials for potential yield gains for Australian crops, even those crops grown in systems and environments significantly different from those targeted by the international centres:
- b) Australian producers will be affected by the price implications of the successful research that is undertaken by the international centres such as ICRISAT, whether or not they take advantage of the possible yield gains spilling over;
- c) Consumers, which for feed grains in developed countries means livestock industries, are likely to be significant benefactors of any research advance in the grains industries:
- d) Australia's gains from international spillovers are likely to be greatest for those industries where there are significant links between Australia researchers and the researchers and programs being undertaken in the international research centres;
- e) Australian researchers need to maintain their vigilance over international agricultural research developments. Because of the contributions of the international centres, producers throughout the world are becoming more efficient and prices are falling. There is a need for a strong domestic research program, partly to maximise benefits from international spillovers, to ensure that Australian producers achieve gains similar to those of their competitors.

Recognition of these factors can assist in leading to better-informed decision-making for research resources, and is likely to lead to a more efficient and more cooperative research system worldwide. That

improved system will deliver expected improvements in the efficiency of production and in the delivery of appropriate food cheaply to the consumers most in need of it.

1.1.3 Impact to Investments in Crop Breeding: the Case of Okashana 1 in Namibia

by D.D. Rohrbach, W.R. Lechner, S.A. Ipinge and E.S. Monyo

Background

Almost 80% of cropped area in Namibia are sown to pearl millet. It is the staple food and the principal source of food security for the majority of the country's smallholders. It accounts for an estimated 24% of total calories intake and roughly 40% of cereal grain intake by Namibian consumers (SADC Regional Early Waning Unit, 1997). But limited rains and frequent droughts reduce average pearl millet yields to less than 400 kg ha⁻¹. In drier years, yields fall below 200 kg ha⁻¹. Namibia's pearl millet breeding program in partnership with ICRISAT released Okashana 1 in 1989 which has early maturity, higher average grain yields, and an improved probability of harvest, when rainfall is poor. It allows farmers who sow with the first rains to obtain a grain harvest 30 to 50 days earlier than are possible with traditional varieties. The new cultivar allows farmers to sow a late and still obtain a harvest. And multiple sowing help farmers distribute their labor more evenly over the cropping season and thus improve the timelines of sowing, weeding and harvesting. The purpose of this study was to identify the reasons for rapid adoption of Okashana 1 in Namibia and to quantify the impact of Okashana 1 to farmers and consumers of pearl millet in Namibia.

Methodology

An *ex post* investment analysis was conducted of the returns to the development and dissemination of Okashana 1. The analysis uses an economic surplus approach to estimating the returns to research and extension investments. This method considers the economic gains derived from a shift in the productivity of pearl millet production corresponding with a downward shift in the pearl millet supply function. The productivity gains translate into benefits to producers, in terms of lower costs of production and benefits to consumers associated with the availability of grain product at a lower price than would be the case if the new varieties had not been developed. The combination of gains to producers and consumers represents an economic surplus to the national economy.

Results and Discussion

Okashana 1 is grown on almost 50% of the national pearl millet area. This success can be explained by three major factors. First, Okashana 1 was quickly identified from the nurseries of an international research program, ICRISAT, as suited to Namibia's needs and adapted to local agro-ecological conditions. Rather than having to develop a new variety from its own limited germplasm stocks, Namibia could quickly exploit the ICRISAT's global germplasm base for pearl millet introductions. The use of this germplasm base was strengthened by the advisory assistance of ICRISAT's pearl millet breeders. Secondly, national scientists had the foresight to consider the preferences of small-scale farmers from the earliest stages of the national variety selection effort. Farmers dependent on pearl millet production chose Okashana 1 from among the 50 entries in Namibia's first observation nursery, quickly recognizing the value of early maturity as a complement to their later maturing traditional varieties. Only three years of joint researcher and farmer observation were necessary before the variety was released. Finally, the rapid

adoption of Okashana 1 was stimulated by public investments in seed production and dissemination. Donor and government support enabled seed to be rapidly multiplied, and sold through national extension programs. The success of these investments has laid the foundation for the privatization of national pearl millet seed supply. A seed growers' cooperative has been established. Seed production and marketing subsidies are currently being withdrawn.

The main advantage of Okashana1 in the northern Namibian cropping system is its early maturity. This allows farmers greater flexibility in their management practices. Most of the farmers also reported that the main reason for their interest in Okashana1 was due to its early maturity (Table 1). Grain yield, grain size and drought tolerance were also cited as priority traits. Farmers commonly and consistently cited three problems associated with Okashana1. These are: weak stem which causes plants to lodge at the end of the season, low stover yield, and softness of the grain.

Table 1. Percentage of households identifying alternative grain traits as the most important justification for adoption (top 5 traits only), 1992/93 season.

Reasons	Northcentral Region	Kavango
Early maturity	45.3	30.4
Grain yield	18.6	18.7
Grain size	15.1	21.5
Drought tolerance	14.0	15.3
Grain color	7.0	13.9

Source: Friis-Hansen and Rohrbach, 1993.

Okashana 1 has led to a net improvement in the welfare of the majority of Namibia's pearl millet producers and consumers. An internal rate of return (IRR) has been calculated and the net present value (NPV) of research assuming a discount rate of 5% and 10%. The results of this analysis reveal the relative gains derived from a low cost breeding program that quickly identified and disseminated a new set of pearl millet varieties. The Government of Namibia, in combination with ICRISAT, received a 50% internal rate of return on their US\$3.0 million investment in the Namibian pearl millet improvement program. The net present value of this return was more than US\$10 million in 1998. Such gains amply justify larger investments in seed multiplication and dissemination. Sensitivity analysis showed that if the adoption of Okashana 1 was delayed by three years and adoption lagged by 50%, the *ex post* rate of return

to investment would have declined to 18%. Such results, though approximate, and somewhat speculative, highlight the value of the early release of new varieties, as well as timely investments in seed multiplication and distribution.

Most of the additional production serves to reduce the cereal grain deficits commonly experienced by pearl millet farmers and improve food security among smallholder families. The higher production also reduces the country's dependence on grain imports. Further, the research investments underlying the development of Okashana 1 have also laid the foundation of a national pearl millet improvement program which did not previously exist. This program has already identified two additional pearl millet varieties—Kangara and Okashana 2—improving on the qualities of Okashana 1. These are based, in part, on local germplasm and partly on further introductions from the international research community. In effect, the investments underlying the development of Okashana 1 also were investments in building a national breeding program.

Conclusions and Lessons for the Future

The experience of Namibia has highlighted three major factors contributing to the success of a national breeding program - strong assistance from an international research center such as ICRISAT, close collaboration with the ultimate clientele of the national pearl millet research program - the farmer, and complementary investments in seed production. High level of return resulted from the use of germplasm originally developed by ICRISAT. Close collaboration between ICRISAT and Namibian breeders and strong links with the Namibian farming community reduced time and research costs and speeded variety adoption. Continuing collaboration between the three partners led to the release of two additional pearl millet varieties in 1998. Both the new varieties have highly favorable prospects for adoption. The strength of this collaboration may serve as a model for pearl millet breeding programs in other parts of the world.

1.1.4 Genetic Diversity and Yield Stability: The Case of Sorghum in India

By U.K. Deb, M.C.S. Bantilan, B.V.S. Reddy, P.B. Cox, and N.K. Rao

Background

The genetic diversity in a crop species is essential to its stability and improvement. Low levels of genetic diversity of cultivars increase the possibility that an unexpected pest or disease could cause a major loss in the production of most or all cultivars of a crop. Numerous examples exist of epidemics caused by low levels of nuclear and cytoplasmic genetic diversity, including the blight disease of northern hemisphere temperate potatoes in the 1840s and the southern corn leaf blight epidemic of maize in the USA in 1970 (McIntyre et al. 1997). Critiques of green revolution argue that green revolution has reduced genetic diversity and increased the variability in crop production and, thereby, increased food security threats. The objective of this study is to establish the relationship between genetic diversity and yield stability. Empirical confirmation is achieved using farm level data on sorghum in India for the period 1966-94. Adoption and yield trends are analyzed to measure the impact of improved genetic diversity on yield stability.

Research Methodology

Methods for measuring this relationship are applied, using genetic diversity index (Souza et al., 1994) and stability indices (Cuddy-Della Valle index). Taking the case of sorghum in India, an empirical analysis was carried out to test the hypothesis that genetic diversity has an impact on yield stability. District level yield data covering 146 sorghum-growing districts in seven states, namely, Madhya Pradesh, Andhra Pradesh, Karnataka, Tamil Nadu, Maharashtra, Gujarat, and Rajasthan of India for the period 1966-94 were used to estimate stability indices. These districts together accounted for about 96 percent of total sorghum area and 95 percent of sorghum production in India (1991-93 average). For estimation of genetic diversity, data on variety specific area under sorghum was collected and validated via rapid appraisal and Delphi technique. Data for specific cultivars gathered from crop statistics published for different states was complemented by elicitation/validation from experts. Experts include specialists working in various research institutions, private seed companies, state seed certification agencies, national seed development corporation, state seed development corporations, directorates of agriculture, Training and Visit (T&V) Offices, and seed dealers.

The genetic diversity in a crop may be determined by analysis of the parentage of crop cultivars grown (Cox et al. 1985; Souza et al. 1994). The Coefficient of Diversity (COD) indicates the degree to which a single cultivar and its related germplasm dominate a region. This is measured conceptually as the converse of generalized similarity index, i.e., $COD = 1 - COP$, where, COP is the coefficient of parentage (COP) which summarizes genealogical similarities between pairs of cultivars. Each cultivar has a COP with itself of 1, and each pair of cultivars without any common parentage has COP of 0. Assuming each parent contributes equally to the progeny, then with unrelated parents the COP between parent and offspring is 0.5 (St Martin, 1982 and Souza et al. 1994). It may be noted that the higher the COD value the greater the genetic diversity within the cropping system.

In this analysis, the three types of diversity are estimated: (a) average annual diversity within particular years; (b) temporal diversity (comparing diversity at the start and end of periods); and (c) recommended diversity, based on variety recommendations from the local research systems. A total of 182 improved sorghum cultivars (122 public notified cultivars and 60 private proprietary hybrids) are determined to be grown in farmers' fields in India. But pedigrees of only 77 cultivars were successfully traced. So this analysis is primarily based only on these 77 cultivars which will tend to under-estimate the diversity level. To overcome this limitation, further analysis was conducted using all of the 182 cultivars under a restricted assumption that a cultivar with unknown parentage is not related to any other cultivar i.e., they are assumed to have no common parentage. This is likely to over-estimate the actual level of diversity prevailing in the farmers' field. It is expected that the actual level of diversity would be somewhere between the two estimates.

Yield instability index. Analysis of yield variability and instability in sorghum was undertaken for two periods—1966/67 to 1980/81, and 1981/82 to 1993/94. The percentage of improved sorghum area to the total sorghum area in India was less than 20% during the first period, increasing to more than double during the second period. Cultivation of improved sorghum cultivars significantly intensified during this period of two and half decades. While the coefficient of genetic diversity among the improved cultivars was very low in the first period, it seemed to increase significantly during the second period. The objective of this analysis is to confirm the hypothesis that while period 1 may be classified as low genetic diversity period, period 2 is a genetically more significant diversified period for sorghum cultivation.

Yield instability was measured using the Cuddy-Della Valle index. Whereas the simple coefficient of variation over-estimates the level of instability in time-series data characterized by long-term trends, the Cuddy-Della Valle index corrects the coefficient of variation, by:

$$CV = (CV^*) (1 - R^2)^{0.5}$$

Where, CV is the Cuddy-Della Valle index, i.e., corrected coefficient of variation (CV). In subsequent discussion it is referred either as CV or instability index. CV* is the simple estimate of the coefficient of variation (in percent), and R^2 is the coefficient of determination from time-trend regression adjusted by the number of degrees of freedom. Z statistics was computed to test the differences in CV between the two time periods.

Results and Discussion

Adoption of improved sorghum cultivars. The rate of adoption of improved sorghum cultivars in India is comparatively slower than improved cultivars of rice and wheat. Rapid rate of adoption occurred in Tamil Nadu and Maharashtra while very slow rate of adoption was observed in Rajasthan and Gujarat states. In India, initial rapid adoption of CSH 1 was evident, as is the subsequent adoption of CSH 5, CSH 6, CSH 9. The farmers to a large extent also adopted MSH 51, popularly known as Mahyco 51. More recently, JKSH 22 is gaining its ground. Contrary to the general expectation, the adoption of hybrids was more than that of improved varieties in India. Improved varieties tended to be less known to farmers than

the hybrids since hybrids provide higher yield and are made available by a large number of private and public seed companies.

The estimates of area under different sorghum cultivars for India are given in Table 1. Three phases in the spread of improved sorghum cultivars in India was observed. During the first phase (upto 1975), only CSH 1 was dominant. During this period, improved sorghum cultivars (CSH 1) mainly replaced the traditional local cultivars. The second phase (between 1976 and 1986) was dominated by the next generation of hybrids, namely, CSH 5 and CSH 6. This phase was characterized by replacement of traditional and initial improved cultivars (CSH 1, CSH 2, CSH 4) by new cultivars (CSH 5, CSH 6). The third phase (which started after 1986) saw the replacement of earlier cultivars from the public as well as private sectors (CSH 9, MSH 51, JKSH 22) at a faster rate. More recently, farmers were introduced to a large number of private hybrids in the market.

Trends in genetic diversity. The analysis of genetic diversity are summarized in Tables 2 and 3. Presented at five-year intervals from 1966 to 1994, the extent of diversity is shown to have increased remarkably over almost three decades. The numerical values of average diversity and recommended diversity of sorghum in India are shown to be identical because all the recommended sorghum cultivars are grown in India, even though the area under majority of these cultivars is small. These estimates, to some extent, over estimates the actual diversity level in the farmers field since the average and recommended diversity estimation do not consider the coverage of the cultivars. Computing the weighted diversity in sorghum cultivation in India as an aggregate using data for all states and for seven major sorghum growing states (Andhra Pradesh, Gujarat, Karnataka, Maharashtra, Madhya Pradesh, Rajasthan, and Tamil Nadu), the level of weighted diversity is seen to be higher in 1994 than in 1966 (Table 3).

Changes in average yield and instability in yield. Table 4 presents the level and changes in average yield and relative variability in yield between the two periods. In period 1 (1966/67 to 1980/81), the highest level of per hectare yield was achieved in Karnataka (985 kg) followed by Tamil Nadu (943 kg) and Madhya Pradesh (729 kg). The lowest yield levels are noted in Rajasthan (300 kg), and Gujarat (499 kg). In period 2 (1981/82 to 1993/94), the highest per hectare yield was observed in Tamil Nadu (1113 kg) followed by Karnataka (957 kg) and Maharashtra (902 kg). Lowest yield level was in Rajasthan (412 kg), followed by Gujarat (551 kg) and Andhra Pradesh (661 kg). A comparative analysis of yield levels for these two-time period show a general increase except for Karnataka where per hectare sorghum yield has been reduced by 28 kg. Average yields in India were 582 kg during Period 1 and 748 kg during Period 2.

Turning to the yield instability index, it is found that in all the states except Gujarat, the coefficient of variation in yield has declined. Noting that Gujarat contributes less than 3% of total sorghum production and 5 % of total sorghum area in India during 1991-94 period, this implies that the relative variability in sorghum yield has generally gone down. At the aggregate level, the coefficient of variation in sorghum yield in India during these two periods was 11 and 13%, respectively.

The analysis of the Z statistics showing the significance in differences in CV between the two periods showed that about 26% of the districts of India are shown to have experienced significant increase in CV and these districts comprised only 14% of total sorghum area in India. On the other hand, 39% of the districts of India experienced significant decline in CV and those districts comprised 42% of total sorghum area in India. This observed reduction in yield fluctuation over the years is expected to have improved food security in most of the sorghum producing areas in India.

Relationship between adoption of improved cultivars, genetic diversity and yield instability. The relationship between the spread of improved cultivars and weighted index of genetic diversity is shown in Table 5. The rate of adoption as well as the genetic diversity in all the states has increased over time except Rajasthan. In Rajasthan, improved cultivars were neither adopted at a large scale nor was there any increase in genetic diversity among the improved sorghum cultivars. The general situation in all the states (except Rajasthan) is that sorghum breeders were using different parental materials to develop new improved cultivars rather than depending only on few parent materials. The breeders were successful in utilizing a large genetic pool to increase diversity. The relationship between genetic diversity and yield instability can be observed from Table 6. Genetic diversity in sorghum cultivation has increased in Andhra Pradesh, Karnataka, Madhya Pradesh, and Tamil Nadu and at the same time, the index of yield instability has declined in these states. In Maharashtra, genetic diversity remained at about the same level in period 2 as in period 1. The variability situation was also similar in these two periods. In Rajasthan, relative variability declined along with the decline in genetic diversity. Overall, yield stability levels improved in all the major sorghum producing states of India, along with the increase of genetic diversity.

Conclusions

This study has three important outcomes. First, the analysis of the three phases of adoption featured the replacement of traditional varieties with new generations of improved sorghum cultivars. Second, genetic diversity among improved cultivars has increased remarkably over time. Third, a significant improvement in yield stability was observed and correlated with the uptake of improved sorghum cultivars which had resultant genetic diversity in sorghum.

Table 1. Area ('000 ha) under popular sorghum cultivars in India, 1966-93.

Cultivar	1966	1971	1976	1981	1986	1991	1993
CSH 1	190.5	694.3	968.8				
CSH 5			1453.2	1941.0	2200.0		
CSH 6				1941.0	2200.0		
CSH 9					1100.0	5420.8	4051.8
MSH 51						1016.4	1688.3
JKSH 22							540.2
Other improved						338.8	472.7
All improved	190.5	694.3	2422.0	3882.0	5500.0	6776.0	6753.0
Local	17809.5	16082.7	13350.0	12717.0	10448.0	5583.8	6128.7
Total	18000.0	16777.0	15772.0	16599.0	15948.0	12359.8	12881.7

Table 2. Coefficient of diversity (average and recommended) in sorghum in India, based on 182 cultivars.

Year	Diversity index
1966	0.25
1971	0.92
1976	0.95
1981	0.97
1986	0.98
1991	0.99
1994	0.99

Table 3. Coefficient of diversity (weighted) in sorghum in India by state.

States	1966	1971	1976	1981	1986	1991	1994
Results based on 77 cultivars							
Andhra Pradesh	0.00	0.00	0.48	0.25	0.32	0.36	0.74
Gujarat	0.00	0.00	0.34	0.56	0.25	0.27	0.28
Karnataka	0.00	0.00	0.41	0.45	0.47	0.60	0.69
Madhya Pradesh	0.00	0.00	0.46	0.46	0.44	0.55	0.64
Maharashtra	0.00	0.00	0.46	0.52	0.48	0.45	0.50
Rajasthan	0.00	0.00	0.34	0.56	0.25	0.27	0.36
Tamil Nadu	0.00	0.00	0.32	0.38	0.50	0.63	0.69
India	0.00	0.00	0.47	0.48	0.45	0.55	0.72
Results based on 182 cultivars							
Andhra Pradesh	0.00	0.00	0.84	1.00	1.00	1.00	1.00
Gujarat	0.00	0.00	0.36	0.94	1.00	1.00	1.00
Karnataka	0.00	0.00	0.49	0.91	0.99	0.99	1.00
Madhya Pradesh	0.00	0.00	0.53	0.94	0.98	1.00	1.00
Maharashtra	0.00	0.00	0.54	0.92	0.98	1.00	1.00
Rajasthan	0.00	0.00	0.36	0.94	1.00	1.00	1.00
Tamil Nadu	0.00	0.00	0.36	0.94	1.00	1.00	1.00
India	0.00	0.00	0.56	0.94	0.99	1.00	1.00

Table 4. Average yield and relative variability in yield of sorghum in different states of India.

States	Period I (1966-80)		Period II (1981-93)		Percentage change	
	Yield kg/ha	CV(%)	Yield kg/ha	CV(%)	Yield (kg/ha)	CV(%)
Andhra Pradesh	521	23.02	661	21.66	26.84	-5.91
Gujarat	499	31.55	551	42.51	10.38	34.76
Karnataka	985	26.65	957	23.08	-2.91	-13.40
Madhya Pradesh	729	24.08	896	19.52	22.76	-18.96
Maharashtra	609	29.50	902	26.51	17.99	-6.71
Rajasthan	300	58.62	412	50.77	37.47	-13.40
Tamil Nadu	943	28.13	1113	26.24	17.99	-6.71
INDIA	582	10.59	748	13.02	28.47	22.97

Table 5. Relationship between adoption of improved cultivars and coefficient of weighted diversity among sorghum cultivars.

States	Adoption Rate (%)			Genetic Diversity Index (COD)		
	1968	1981	1993	1966	1981	1994
Andhra Pradesh	0.56	20.28	46.76	0.00	0.25	0.74
Gujarat	0.15	7.78	53.16	0.00	0.56	0.28
Karnataka	3.03	22.76	22.97	0.00	0.45	0.69
Madhya Pradesh	0.92	29.17	49.48	0.00	0.46	0.64
Maharashtra	8.47	30.02	68.09	0.00	0.52	0.50
Rajasthan	0.42	4.64	1.52	0.00	0.56	0.36
Tamil Nadu	1.35	27.65	99.31	0.00	0.38	0.69
INDIA	3.68	23.39	52.42	0.00	0.48	0.72

Table 6. Coefficient of weighted diversity and instability in sorghum yield in different states of India.

States	Genetic Diversity Index (COD) in year		% change in COD	Index of yield instability		% change in instability index
	1981	1994		Period I	Period II	
	Andhra Pradesh	0.25	0.74	196.00	23.02	21.66
Gujarat	0.56	0.28	-50.00	31.55	42.51	34.76
Karnataka	0.45	0.69	53.33	26.65	23.08	-13.40
Madhya Pradesh	0.46	0.64	39.13	24.08	19.52	-18.96
Maharashtra	0.52	0.50	-3.85	29.50	26.51	-6.71
Rajasthan	0.56	0.36	-35.71	58.62	50.77	-13.40
Tamil Nadu	0.38	0.69	81.58	28.13	26.24	-6.71
INDIA	0.48	0.72	50.00	10.59	13.02	22.97

1.1.5 Adoption and Impact of New Sorghum Varieties in Botswana

By D.D. Rohrbach and E. Makhwaje

Background

Sorghum accounts for 84% of the area planted to cereal grains in Botswana. Yet the country imports at least one-half of its sorghum requirements, and over 70% of its total cereal grain supplies (FAO, 1998). National sorghum yields remain extremely low, averaging 200-300 kg ha⁻¹. Most production is semi-subsistence.

The future of Botswana's sorghum-based farming system depends on improving crop productivity to the levels necessary to provide a sustainable livelihood to the nation's farmers. This requires the development and dissemination of improved production technology. Incentives to apply this technology also need to be improved.

In 1994, the Government of Botswana released four new sorghum cultivars--three open pollinated varieties and one hybrid. The three varieties, Phofu, Mmabaitse and Mahube, were targeted towards improving production in the nation's smallholder sector. The white-grained Phofu offered good drought resistance and larger grains with good milling quality. Mmabaitse, another white-grained variety, was similarly released for its drought tolerance. Mahube, a red-grained variety, offered early maturity and good malting quality. The hybrid, BSH1, was targeted towards more commercialized farmers in the Pandamatenga farming area. This cultivar offered a combination of high productivity under commercial farming conditions with its good milling characteristics.

Methodology

Three surveys were conducted to evaluate the acceptability of the new varieties to small-scale farmers. First, a reconnaissance survey reviewed the basic parameters of adoption. This survey, conducted in late March and early April 1996, examined whether farmers understood the difference between the new varieties, and outlined the variety evaluation criteria important to farmers (Rohrbach et al. 1996). The reconnaissance covered two of four major sorghum production regions in the country: the Francistown Region and the Central Region. More than 35 farmers and 7 extension staff were individually interviewed.

A formal survey was conducted in 1997 to quantify the response to the new varieties among a wider cross-section of Botswana's farm population. This principally evaluated the extent of replanting of seed harvested in 1996. By scheduling the survey after the completion of the planting season, farmers could also be asked about crop performance as evidenced the 1996 harvest.

This survey encompassed a random sample of farmers from the four major sorghum growing regions of the country: the Francistown, Central, Gaborone and Southern regions. Two districts were randomly chosen in each region. Then 2 villages were randomly chosen in each district. Finally, eight small-scale farm households were selected at random from census lists of the farmers in each village. This was the primary sample from which adoption data could be drawn.

This sample was supplemented with a secondary sample of up to four additional households with experience growing at least one of the new varieties. The secondary sample was selected to ensure the availability of a larger sample of households with experience necessary to evaluate the new varieties. If at least 4 of the 8 randomly chosen households had experience with the new varieties, no supplementary sample was selected. However, if less than 4 households had experience with the new varieties, supplementary households were interviewed to gain a minimum sample of 4 farmers with experience. Data from the full primary and secondary sample was analyzed when evaluating the performance and acceptability of the various sorghum varieties.

The total primary sample was 128 households. The secondary sample was made up of 17 additional households. The survey interviews were carried out between 1 May to 30 June 1997. A follow-up survey was conducted following the 1997/98 planting season - in March-April 1998. This covered the same sample as the 1997 survey.

Results and Discussion

The initial adoption of those varieties was stimulated by government investments in seed multiplication and distribution. Under a drought relief program during the 1995/96 planting season, 440 t of Phofu seed were freely distributed. Smaller quantities of Mmabaitse (27 t) and Mahube (20 t) seed were also given out to farmers. An initial 2.6 t of BSH1 seed were sold. However, during the following two years, no seed was distributed for drought relief, and the sale of sorghum seed was limited.

Small-scale farmers had developed a dependence on free deliveries of sorghum seed during the previous decade. The unexpected termination of free seed deliveries contributed to a fall in national adoption rates for the four sorghum cultivars. While virtually 90% of the nation's sorghum farmers are aware of Phofu, and 46% have tried this variety, only 21% planted it during the 1997/98 cropping season. Less than 10% of Botswana's farmers have had the opportunity to test Mmabaitse or Mahube. Fewer than 2% of Botswana's farmers have tried the hybrid BSH1.

Botswana's experience highlights the importance of linking variety release with strong seed multiplication and distribution programs. Limited distribution of seed constrains even the possibility of a favorable return on investments in crop breeding. The Government of Botswana has long subsidized the production and distribution of sorghum seed. The following analysis suggests opportunities for better targeting these subsidies to promote the distribution of new varieties, in particular.

The impact of Botswana's sorghum improvement program largely depends on the productivity gains offered by the new cultivars. Unfortunately, available experimental evidence indicates farmers will not improve their productivity by adopting the three open pollinated varieties. This is confirmed in yield data obtained from farmers. While Phofu offers comparable yields to Segalane, the main sorghum variety traditionally grown by smallholders, Mmabaitse and Mahube seem to yield less. The hybrid cultivar, BSH1, seems to offer the prospect for more consistent yield gains. However, further information is needed on variety performance under the low input conditions characteristic of sorghum production by small-scale farmers.

Larger gains in sorghum productivity will only be obtained from improvements in crop management. This is evident in the large gap between sorghum yields on experiment station and those on farmers' fields. The new sorghum varieties commonly offer grain yields of 1.0 and 3.0 t ha⁻¹ on the experiment station. These yields drop to 0.3 to 0.5 t ha⁻¹ in on-farm trials. The average grain yields derived from new and traditional varieties drop even further under non-trial conditions. Despite more than a decade of agricultural production subsidies, the adoption of improved management practices is extremely limited. As a result, average sorghum yields nationwide remain between 0.2 and 0.3 t ha⁻¹.

Unless sorghum productivity is improved, the area planted to this crop will decline and Botswana will import a growing share of its sorghum requirements. This requires larger investments in improved soil and water management. The chief prospect for encouraging this investment lies in the commercialization of sorghum production targeted toward the small-scale milling industry. There are currently 68 small-scale sorghum mills in the country. Most of these have been established within the past 5 years. These millers currently obtain over 90% of their grain input from South Africa, largely because of the ease and consistency of this grain supply. However, many of these millers would prefer to purchase domestically produced sorghum because this offers a preferred white color and the flour has a better taste. Millers have expressed particular interest in both Phofu and BSH 1.

Conclusion

The achievement of both higher rates of variety adoption, and complementary investments in improved management, depend on strengthening the linkages between national sorghum scientists, input suppliers, and the milling industry. Each of these stakeholders needs to agree on common goals for technology improvement, as well as a plan of action for their implementation. In effect, this would replace a government led strategy to subsidize the adoption of better technology with a more commercial strategy based on evolving pattern of grain market demand. Such demand-led strategies of technological change offer greater prospects for research impact.

1.1.6 Assessment of the Economic Impact of Sorghum Variety S 35 in Chad

by A.M Yapi, G. Dehala, K. Ngawara, and A. Issaka

Background

The S 35 sorghum variety is a nonphotoperiod-sensitive, high-yielding, early-maturing, and drought-tolerant pure line that originated from ICRISAT's breeding program in India, and was later advanced and promoted in Cameroon and Chad. It was introduced into drought-prone areas of Chad through the collaborative effort between ICRISAT and the Direction de la recherche et de la technologie agricoles (DRTA), the principal government agency responsible for agricultural research in Chad. The main objective of the study was to evaluate the economic impact of the research and development (R&D) and diffusion of the S 35 sorghum technology in Chad.

Methodology

In this study, survey methods were used to (a) track the spread of the technology, (b) quantify the extent of its adoption, (c) collect the necessary information to assess its impact. On-farm inquiries were carried out in 1995 through a formal survey using structured questionnaires. The survey involved selection of representative sample farms using multi-stage sampling. A sample of 152 farmers from 28 villages in four subprefectures all randomly selected from the three prefectures – Gue'ra and Chari-Baguirmi (in the Sahelian Zone) and Mayo-Kebbi (in the Sidan-sahelian Zone)—targeted by the release of S 35 in Chad. The three prefectures – Gue'ra, Chari-Baguirmi, and Mayo-Kebbi – selected for this study fall largely in the targeted research zones of S 35. Together, these three regions produce on average 47% of the total output of annual rainfed sorghum in Chad, using 42% of the total harvested area of rainfed sorghum. A survey questionnaire with multiple modules covering cropping systems, adoption patterns, farmer's perceptions and perspectives, farm cost structure, yield, and the utilization of seed, labor, and fertilizer inputs was used to collect the farm-level information. These were used to evaluate the impact of the S 35 technology in the selected prefectures.

Economic surplus approach was used in this study to evaluate returns to S 35 research and diffusion investments. Because international trade in sorghum is practically nonexistent in Chad, a simple, non-traded commodity model of the economic surplus approach was applied for impact evaluation. This simple framework is a single-period static model of a closed economy with a parallel shift in the supply function. It compares economic surpluses with and without S 35 research and diffusion.

Results and Discussion

Patterns of adoption. Results of the adoption surveys confirmed that within six years of its release, S 35 had spread quite significantly in the zones targeted by research and extension activities, especially in the drought-prone Gue'ra (Table 6). The adoption rates varied between regions. They are higher and increase more rapidly in the totally Sahelian Gue'ra than in the

Sudan-Sahelian Mayo-Kebbi and Chari-Baguirmi. Apart from ecological differences, the differential rates of adoption in the three regions can, perhaps, be better explained by the quantity of pure seed made available to farmers in each region. As the primary release target zone, Gue'ra benefited, not only from most of the S 35 extension services provided by ONDR and NGOs, but also from the large-scale pure seed production campaign that was initiated two years before the variety was formally released. Adoption of S 35 in Mayo-Kebbi started slowly. In 1990, the adoption rate was only 7% but by 1995 it had increased to 27%. This is quite spectacular for a region where seed distribution is severely limited by poor road infrastructure, and where consumer preferences favor red- as opposed to white-grained sorghum varieties such as S 35. Adoption of S 35 in Chari-Baguirmi did not begin until two years after its release. The initial rate of adoption was rather high (14% in 1992). Three years later (i.e., 1995), the rate of adoption had increased to 24%. This is also quite impressive for a region where preliminary on-farm test results had discouraged intensive extension activities by ONDR. These results are the fruits of individual activities by isolated NGOs [(e.g., Secours catholique pour le développement (SECADEV), Cooperation for American Relief Everywhere (CARE), and Voisins Mondiaux]. The patterns of adoption and the corresponding areas sown to S 35 clearly indicate that farmers in the drought-prone regions of Chad have started replacing their long-cycle landraces with the short-duration S 35 sorghum variety.

Farmers' perceptions. Why are farmers eager to adopt the S 35 technology? Why are they willing to change their management practices for the S 35 sorghum variety but not for local varieties? The on-farm surveys provide a two-fold answer to these questions. Firstly, farmers prefer S 35 over traditional varieties because the new technology is early-maturing, high-yielding, and has good food and fodder characteristics. The short-duration trait of S 35 is an obvious advantage in drought-prone areas where farmers' long-cycle local varieties frequently fail due to delayed or inadequate rainfall. Other reasons cited by farmers are: the recommended management practices for S 35 adoption are simple, relatively easy to implement with available family labor and animal traction, and are not capital intensive.

Constraints to adoption. The three major constraints cited by farmers-susceptibility of the variety to bird attack, the high cost of seed, and low soil fertility- should assist in the formulation of future research priorities.

Economic benefits from S 35 adoption. The estimated yield advantage of S 35 over the best of farmers' traditional technologies was substantial, and ranged from 46% in Chari-Baguirmi to 53% in both Mayo-Kebbi and the Guéra. The cost analysis of farm-level production indicated that by using the S 35 technology, farmers achieved a significant per unit production cost reduction. The per unit production cost reductions were estimated at about 23 000 CFA francs t^{-1} (i.e., US\$ 46 t^{-1}) for the Guéra, 8000 CFA francs t^{-1} (i.e., US\$ 16 t^{-1}) for Mayo-Kebbi, and 18 000 CFA francs t^{-1} (i.e., US\$ 36 t^{-1}) for Chari-Baguirmi.

Economic Surplus Analysis showed that the net present value (NPV) of benefits from the adoption of S 35 is estimated at US\$ 15 million (or 7.5 billion CFA francs) for the three regions as a whole at a discount rate of 10%. This represents an internal rate of return (IRR) of 95%. Subsequent sensitivity analyses showed that the NPV and IRR do not vary with alternative parameter values. Regional benefits analyses were also conducted which showed higher benefits for the Guéra region (where rates of adoption were higher) than for the other two regions (where rates of adoption were lower). Distributions of gains were in favor of consumers (62.5% as opposed to 37.5% for producers).

Conclusions

This study highlights the importance of the germplasm spillover, i.e., the extent to which scientists and farmers in Nigeria, Cameroon, and Chad used a genetic material first developed in India. This is an important consideration in international agricultural research, as research activities are more often than not planned around mandate crops and agroecological zones, which are found in different parts of the world. The sharing of germplasm by national and international research institutions through collaboration and networking has been emphasized. This is particularly important for national agricultural research systems (NARS), especially the less endowed ones, which could take advantage of research on similar agroecological zones. The knowledge thus obtained could then be adapted quickly to the specific local environment at limited research costs.

Table 1. Adoption of S 35 (as % of total rainfed sorghum area) in the Gue'ra, Mayo-Kebbi, and Chari-Baguirmi, Chad, 1990-95.

Year	Gue'ra	Mayo-Kebii	Chari-Baguirmi	All three regions
1990	17(14) ¹	7(14)	0(0)	7
1991	22(23)	8(15)	0(0)	8
1992	23(41)	10(28)	14(40)	14
1993	28(58)	17(47)	21(80)	20
1994	32(84)	22(72)	22(60)	24
1995	38(84)	27(75)	24(80)	27

1. Numbers in parentheses are percentages of farmers who adopted the technology.

1.1.7 Impact of Germplasm Research Spillovers: The Case of Sorghum Variety S 35 in Cameroon and Chad

by A.M Yapi, S.K. Debrah, G. Dehala, and C. Njomaha

Background

Germplasm movements between institutions constitute an important building block of the world agricultural research. ICRISAT has a policy to distribute a wide range of parental materials to breeding programs of the national agricultural research systems (NARS) and the private seed sector (ICRISAT 1995). This has contributed to faster and cost-effective development of useful final products by the receiving parties. The case of sorghum variety S 35, a nonphotoperiod-sensitive, high-yielding and early-maturing pure line developed from the ICRISAT breeding program in India, and later advanced and promoted in Cameroon and Chad, is an outstanding example of this. The main objective of this study was to estimate the benefits of agricultural research spillover effects in the case of S 35 in Cameroon and Chad, individually and as a whole.

Methodology

The survey method was used to track and quantify the spread of the S 35 technology. A structural survey questionnaire with multiple modules was used in each country to collect farm-level information necessary for the impact evaluation. The modules were designed to collect farm-level information on cropping systems, adoption patterns, farmers' perceptions, farm production and cost structure, and seed, labor, farm equipment, and fertilizer inputs utilization. The surveys were conducted in 1995 and covered the periods 1986–1995 (for Cameroon) and 1990–95 (for Chad). Using multiple stage sampling scheme a total of 723 farmers (571 from Cameroon and 152 from Chad) were interviewed. To represent Cameroon, a total of 571 participating farmers were selected from 33 villages in 17 arrondissements within the three purposively chosen zones—Mayo-sava, Diamaré, and Mayo-Danay—of Cameroon. Similarly in Chad, 152 participating farmers were selected from 28 villages in four sub-prefectures within the three purposively chosen prefectures—Mayo-Kebbi, Chari-Baguirmi, and Guéra.

The welfare gains from S 35 research and diffusion in Chad and Cameroon were estimated using the economic surplus framework.

Results and Discussion

Patterns of adoption. Results of the adoption survey clearly indicated that farmers in drought-prone regions of Chad and Cameroon have started substituting the short duration S 35 for their long-cycle landraces (Djigari, Nadj-dadja, Kouran, and Wakas varieties). Ten years after its release in northern Cameroon, the technology has spread over about 50% of the total rainfed sorghum area in Mayo-Sava where 85% of the farmers have adopted it. The spread of the variety has been less spectacular in the other two study zones in Cameroon, where about 20% of farmers cultivate S 35 on less than 15% of their rainfed sorghum fields. These zonal differences in adoption rates are explained mainly by differences in

annual rainfall, which average 687 mm in Mayo-Sava against 819 mm in Diamaré and 811 mm in Mayo-Danay. The lower the annual rainfall, the more valuable short duration varieties become.

In Chad, the spread of the S 35 technology has been spectacular as well, especially in the totally drought-prone Sahelian region of Guéra. Seven years after the variety was released, adoption rates in terms of area reached 38% in Guéra, 27% in Mayo-Kebbi, and 24% in Chari-Baguirmi. These levels of adoption are consistent with the extent of seed availability and the intensity of extension services in each region. They are higher in the Guéra region, which has received the bulk of the seeds produced by the Gassi seed project. The lower but substantial rates observed in Mayo-Kebbi and Chari-Baguirmi are to be credited to a successful campaign by NGOs to distribute improved seeds to farmers in wetter areas not initially targeted by the release of the S 35 variety. Rainfall patterns since 1968 have shown a downward trend with rainfall consistently below the long-term average.

Farmers' perceptions. The on-farm surveys also provided useful information on farmers' perceptions of the S 35 technology. First, farmers have indicated a preference for S 35 over their traditional varieties because the new variety was early-maturing and high-yielding with good food and fodder quality. This was true across all study sites. The short-duration trait of S 35 was an obvious advantage in drought-prone areas where farmer's long-cycle traditional landraces often failed when rains came late and/or ended too soon. In addition, farmers in Mayo-Sava (Cameroon) and Guéra (Chad) have cited the emerging high market value of white-grain sorghum as an important reason for using the S 35 variety. Indeed in the Mayo-Sava zone, a typical bag of 100 kg of white-grain sorghum was valued at CFA francs 9000 (250 CFA francs = US\$ 1.00) against CFA francs 7000 for the most popular red-grain local Djigari varieties (Njomaha et al. 1997). Similarly, in the Guéra zone of Chad, observed local markets prices for white-grain sorghums were higher than prices of local red-grain varieties. This price differential is certainly related to the good food quality of the S 35 flour.

Second, farmers were willing to change their management practices for S 35 and not for their local sorghum varieties because the required changes are simple, familiar, and easy to implement locally from available family and animal labor. Furthermore, payoffs for making these changes are substantial, including food security, production efficiency, and unit production cost reduction.

Constraints to adoption. The adoption and intensive use of the S 35 technology were constrained by a number of factors, the most important of which were bird attack, lack of improved seed, soil/land infertility, grain mold, and the high cost of grinding. The first two of these cut across all study sites, while soil/land infertility was specific to Chad, and grain mold was specific to Cameroon. Farmers in Cameroon have also cited the high cost of grinding as another important constraint to S 35 adoption.

Impacts of S 35. Compared to farmers' best traditional varieties across all study sites in Cameroon and Chad, S 35 yields 27% more output (grain) and reduces unit production cost by 20%. These farm-level impacts are larger in Chad where yield gain is 51% higher and cost reduction is 33% higher. The net

present value of benefits from S-35 research spillover in the African region was estimated to be US\$ 15 million in Chad and US\$ 4.6 million in Cameroon, representing internal rates of return of 95% in Chad and 75% in Cameroon. These impacts were evaluated from the perspective of national research systems. A conscious decision, therefore, was made to include only those costs associated with national research and extension institutions. All other S 35-related research and development expenditures incurred in India and Nigeria were treated as 'sunk costs', that is, costs which would have occurred anyway without spillover. Had each country had to develop S 35 and associated management practices on its own, the time lag between research and release of the technology would have been longer and consequently impacts, if any, would have been smaller. For greater effectiveness in sorghum technology development and transfer in the region, future research and policy actions should take greater advantage of research spillovers through more collaboration, communication, and networking between national, regional, and international research institutions.

Conclusions

S 35 is a product of collaborative research and development by ICRISAT and the Cameroonian and Chadian NARS. S 35 was very successful in the farmers' field of Cameroon and Chad. The study suggests that future sorghum breeding efforts in both of these countries should focus not so much on developing new varieties but rather on removing the constraints identified by farmers and take advantage of research spillovers.

1.1.8 Efficiency and Sustainability Gains from Adoption of Short-duration Pigeonpea in Nonlegume-based Cropping Systems

by M.C.S Bantilan and D. Parthasarathy

Background

A study was undertaken to determine the extent of adoption and impact in Central India of the short-duration pigeonpea variety, ICPL 87. Developed from ICRISAT-derived material, the variety was released in India as Pragati in 1986. The aims of the study were: (a) to determine the rate and extent of adoption of ICPL 87, (b) to document farmer preferences and constraints to adoption, (c) to survey the impact of adoption on efficiency and sustainability.

This paper focuses on efficiency and sustainability, and aims to determine the influence of farmers' concerns regarding sustainable farming on adoption of short-duration pigeonpea (SDP). Using results from a formal on-farm survey and rapid rural appraisals (RRAs) conducted in a drought-prone area in Central India in 1995, the paper illustrates that sustained productivity and efficiency concerns are addressed via appropriate management - in this case, crop rotation with profitable SDP - in order to capture both short- and long term gains.

Methodology

Farm-level surveys covering the pigeonpea growing districts of Central India were conducted, cutting across the boundaries of two semi-arid tropics (SAT) research domains defined by ICRISAT as Production Systems (PS) 7 and 8. These systems represent: (a) the intermediate rainfall, rainy-season sorghum/cotton/pigeonpea cropping system in India's eastern Deccan Plateau (PS 7), and (b) the low rainfall, primarily rainfed, postrainy-season sorghum/oilseed cropping system in the western Deccan Plateau (PS 8).

The survey covered a representative selection of villages and blocks in eight pigeonpea-growing districts of western Maharashtra and northern Karnataka. The survey was spread over 35 villages from which 277 farmers were randomly selected. The selection of the study site was primarily based on background data obtained from a reconnaissance survey of the pigeonpea-growing tracts in PS 7 and PS 8. Field observations and interviews with regional research and extension staff indicated that the diffusion of ICPL 87 occurred in the regions around western Maharashtra. Data on sales of pigeonpea seeds by the public and private sectors confirmed that adoption was widespread in this region. RRAs complemented the formal on-farm survey which focused particularly on the efficiency and sustainability gains of ICPL 87 adoption.

Results and Discussion

Adoption and diffusion. Data obtained from on-farm surveys showed that large-scale adoption of ICPL 87 occurred especially in the northern districts of Dhule (98%), Ahmednagar (89%), and Jalgaon (49%). Farmers in these three districts are classified as early adopters: they took up ICPL 87 soon after its introduction in the region in 1987. The main reasons cited for adoptions are short duration, high yield, improved soil fertility, and high market price.

A substantial rise in the level of adoption during the period 1988 to 1994 was measured. Adoption rates (in terms of percentage of the total area under pigeonpea) increased in western Maharashtra from 3% in 1988 to 35% in 1990 and to 57% in 1994. In northern Karnataka, it rose from 0 to 16% over the seven-year period. In terms of the number of farmers, the rate of adoption grew from 2.8 to 71% in western Maharashtra, and from 0 to 25% in northern Karnataka.

Varying adoption levels were observed across the districts and blocks (Bantilan and Parthasarathy 1995). Out of a total of 17 blocks covered in the survey, 6 blocks had at least 90% of their pigeonpea area covered with ICPL 87, while 3 blocks registered an adoption rate between 42 to 65%. ICPL 87 has so dominated the pigeonpea area in this region that farmers in 10 of the 35 villages studied reported that there was practically no other pigeonpea variety grown in their villages except ICPL 87. In these 10 villages, the estimated adoption level ranged from 91 to 100%.

Impact of adoption. A comparative cost-benefit analysis with the previous best available variety, the medium-duration BDN 2, confirmed higher net benefits from adoption of ICPL 87. Results indicated that the net farm income was higher (30%) for ICPL 87 (Table 1); the grain yield advantage was 93%, and the unit cost reduction around 12% (Rs 1296.36 t⁻¹). The resultant increase in net income obtained by farmers has been crucial for adoption. The survey clearly indicated that, despite the increased cost for irrigation and fertilizer/farmyard manure (FYM), ICPL 87 has had a positive impact on farmers in terms of increased profits at the farm/household level. Intensive cultivation of ICPL 87 as a sole crop, coupled with its emergence as a cash crop, especially in small farm holdings, seems to have resulted in farmers bestowing more care on the crop. Labor use actually increased with adoption. Farmers in some villages also noted that alternative short-duration crops (i.e., hybrid sorghum and sun flower) deplete soil fertility. Table 2 shows the higher net benefits obtained by pigeonpea-based crop rotations as compared to pearl millet- and sorghum-based rotations.

Sustainability dimensions. ICPL 87 is advantageous both to large and small farmers primarily because it allows a second crop in the post-rainy season and it helps to maintain long-term productivity through enhanced soil fertility. ICPL 87 was also frequently mentioned as a boundary crop to prevent soil erosion. Farmers' responses to questions regarding their reasons for adopting ICPL 87 suggest the importance of the sustainability dimension. This is highlighted by the summary of responses to a multiple-response question on desirable traits (Table 3, relative ranks are given in column 4). At least 90% of the respondents cited "short duration" and "increased grain yield" as desirable traits influencing adoption.

Around 49% of the respondents specifically mentioned “improved soil fertility” as a reason for adoption. Importance was also given to “market price” (45%).

Conclusions

This study established an important connection between farmers, concerns regarding sustainable farming and the adoption of improved technologies. It confirmed that farmers are well aware of the effects of intensive cultivation of cash crops, such as sugarcane or cotton in irrigated tracts, in terms of reduced yields and increasing use of inputs. Farmers consciously adopt appropriate crop/variety and management practices to maintain long-term productivity levels for existing and desired cropping systems. Farmers strive to increase or maintain soil fertility by including nitrogen-fixing legumes in crop rotations - in this case, short duration pigeonpea. Widespread adoption of short-duration pigeonpea has made farming profitable in the short term - via cultivation of a second crop in the post-rainy season - and farmers expect to sustain productivity in the long run via crop rotation to maintain soil fertility.

Table 1. Comparative impact of ICPL 87 and BDN 2 in Maharashtra, India.

	ICPL 87	BDN 2
Grain yield (kg ha ⁻¹)	1181.5 kg	611.1 kg
Unit cost (Rs t ⁻¹) ¹	Rs 9146.24	Rs 10 442.00
Net farm income (kg ha ⁻¹)	Rs 5247.03	Rs 4011.73
Unit cost reduction (Rs t ⁻¹)	Rs 1296.36	

1. Indian rupees 36 = US\$ 1.

Source: Pigeonpea Research Evaluation and Impact Assessment (REIA) survey, 1995.

Table 2. Total net benefits from different crop rotations.

Crops	Benefits (Rs ha ⁻¹) ¹
Pigeonpea—onion	2616.20
Pigeonpea—wheat (1)	7010.40
Pigeonpea—wheat (2)	6311.90
Pigeonpea—rabi	4267.20
Soybean—wheat	9728.20
Hybrid sorghum / wheat	2540.00
Pearl millet—wheat	685.80

1. Indian rupees 36 = US\$ 1.

Source: Pigeonpea Rapid Rural Appraisals, Manjoor village, Ahmednagar, Maharashtra, 1996.

Table 3. Farmers' feedback regarding desirable traits of ICPL 87.

Traits	Frequency ¹	Percent	Rank ²
Short duration	133	93	1.00
More grain yield	128	90	.96
Improved soil fertility	70	49	.36
High market price	65	45	.36
Better taste	19	13	.09
Disease resistance	18	13	.10
Less cooking time	15	11	.06
Insect resistance	5	3	.03
Color	4	3	.01
Drought tolerant	4	3	.03
Good fodder quality		1	.01
Bigger grain size	1	1	.01
Others	26	18	

1. Multiple responses were provided by a random sample of 143 farmers.

2. Relative importance of traits is weighted by ranks (r) provided by respondents.

Source: Pigeonpea Research Evaluation and Impact Assessment (REIA) survey, 1995.

1.1.9 Impact Assessment of Crop and Resource Management Technology - A Case of Groundnut Production Technology

by P.K. Joshi and M.C.S. Bantilan

Background

Quantification of adoption and impact of crop and resource management technologies is complex, although this area of research shares a significant proportion of research resources. This study discusses some methodological complexities in assessing the impact of crop and resource management technologies, and estimates the impact and spread of various components of a technology, popularly known as the 'Groundnut Production Technology'. Collaborative research by ICRISAT and the Indian NARS resulted in the development of this technology; some of its components are now used in Indonesia and Vietnam. The technology was developed in 1986, and widely tested on farmers' fields during 1987-91. The technology integrates various crop and resource management options, which includes land management, nutrient management, insect pest and disease management, seed management, and water management. However, one key component of GPT, raised-bed and furrow method of land configuration, was selected to distinguish the adopters of the technology package. Scrutinizing the technology, it was noted that this component distinguished the GPT with the already recommended technology. Therefore, (non) adoption of raised-bed and furrow was used as a guiding factor to identify adopters and non-adopters.

Methodology

The technology was initially tested in eight states of India, but it suited largely to Maharashtra state. A total of 355 farmers in Maharashtra state in India were randomly selected for the study following a multi-stage stratified random sampling technique. Relevant information was collected from the selected farmers through a structured questionnaire; interviews were conducted between late 1994 and mid-1995 to track the adoption of different GPT components.

To quantify the returns to investment on research and technology transfer, three aspects were examined: (i) adoption rates and the spread of different components of GPT, (ii) research and technology transfer cost, and (iii) benefits from the research and technology transfer program. Logistic growth functions were estimated to describe the rate of adoption of each component of the GPT. Economic surplus and distribution of welfare gains due to investment in research and technology transfer program were estimated by assuming a parallel shift in supply function. Internal rates of return, net present values and benefit cost ratios were computed under three options: (i) full adoption of GPT package, (ii) adoption of only management practices, and (iii) adoption of only raised-bed and furrow keeping other practices the same. Sensitivity analysis was also carried out under various assumptions related to changes in research and technology transfer investment.

Results and Discussion

Adoption of GPT. The study found that farmers partially adopted the concept of crop and resource management research products, and modified the technology options according to their needs, convenience and resource endowments. Differential adoption of various components of the technology was observed.

About 31% of the summer season groundnut in the study area were assessed under raised-bed and furrow. The adoption rates for improved varieties were about 84% and for single super phosphate were about 70%. Farmers who cultivated groundnut on raised-bed and furrow also adopted ICRISAT groundnut varieties in about 65% of the groundnut area. The corresponding figure for those who did not adopt raised-bed and furrow method, sown ICRISAT variety in less than 10% of the groundnut area. Gypsum and seed dressing are becoming popular and their adoption reached slightly above 40%. Use of ferrous sulphate and sprinkler irrigation was at the early stages of adoption. It was noted that the adoption of different components was largely associated with the raised-bed and furrow. Adoption of all components was significantly higher with those who adopted the raised-bed and furrow method. The probability of adopting the raised-bed and furrow was high when farmers had access to technology-generating and technology-transfer systems. Availability of appropriate implement, capital and irrigation also determined the adoption of the raised-bed and furrow technology, option.

Farm-level benefits of the GPT. Substantial on-farm benefits were realized by those farmers who adopted the GPT. These include related to yield gains, higher income, better output prices, cost saving, and conservation of soil and water resources. The groundnut production technology gives 38% higher yields, generate 71% more income, and reduces unit cost by 16%. Benefits related to gender and sustainability issues were also realized by the farmers who adopted the components of the GPT. The technology was generating employment and improving labor productivity. It demonstrated some positive implications on gender and sustainability issues.

Economic impacts. Table 1 presents the stream of research and technology transfer cost and the research benefits and estimated net present value, internal rate of return and benefit-cost ratio under different technology options. The analysis revealed that the internal rate of return of GPT was 25.26% if total package of the GPT is adopted. The net present value of information from the research and technology transfer program on GPT was estimated to be US\$ 3.45 million. The benefit-cost ratio was 9.37, which means that US\$ 1 invested in developing and disseminating GPT produced an average benefit of US\$ 9.37 throughout the period.

In case only management practices (including raised-bed and furrow, nutrient management, plant protection measures, etc.) were adopted, the internal rate of return was 19.15%. The net present value was about US\$ 1.4 million with a benefit-cost ratio of 4.39. The rate of return was low (13.5%) if only raised-bed and furrow was compared with the flat method of cultivation. This shows high complementarity between different management practices, especially with raised-bed and furrow. These results confirm farmers' perceptions that raised-bed and furrow yields higher returns if adopted along with other technology components, including improved varieties. The internal rate of return under farmers' partial adoption level was 21.1%. These results clearly reveal that the research and technology transfer investments on GPT package yielded positive returns. It was noted that even the components of GPT were partially adopted, the research and technology transfer investments were justified.

The total net present value of benefits from collaborative research and technology transfer is more than US\$ 3 million, representing an internal rate of return of 25%.

Table 1. Benefit and research and technology transfer cost of full package of the GPT.

Year	ICRISAT Cost 000 US \$	NARS cost 000 US \$	Benefits: Full package 000 US \$	Benefits: Mng ¹ . 000 US \$	Benefits: RBF ¹ 000 US\$
1974	45.6	4.56	0	0	0
1975	45.6	4.56	0	0	0
1976	45.6	4.56	0	0	0
1977	45.6	4.56	0	0	0
1978	45.6	4.56	0	0	0
1979	45.6	4.56	0	0	0
1980	45.6	4.56	0	0	0
1981	45.6	4.56	0	0	0
1982	45.6	4.56	0	0	0
1983	45.6	4.56	0	0	0
1984	45.6	4.56	0	0	0
1985	45.6	4.56	0	0	0
1986	24.0	4.56	0	0	0
1987	20.0	4.56	0	0	0
1988	20.0	4.56	0	0	0
1989	20.0	4.56	162.57	76.15	36.42
1990	10.0	4.56	460.62	215.75	103.19
1991	0.0	7.50	650.29	304.59	145.68
1992	0.0	7.50	1151.56	539.39	257.97
1993	0.0	7.50	1228.33	575.34	275.17
1994	0.0	7.50	1404.45	657.84	314.63
1995	0.0	7.50	1580.57	740.33	354.08
1996	0.0	7.50	1670.89	782.64	374.31
1997	0.0	7.50	1761.21	824.94	394.54
1998	0.0	7.50	1806.37	846.09	404.66
1999	0.0	7.50	1806.37	846.09	404.66
2000	0.0	7.50	1806.37	846.09	404.66
2001	0.0	0.00	1806.37	846.09	404.66
2002	0.0	0.00	1806.37	846.09	404.66
2003	0.0	0.00	1806.37	846.09	404.66
2004	0.0	0.00	1806.37	846.09	404.66
2005	0.0	0.00	1806.37	846.09	404.66
IRR (%)			25.26	19.15	13.50
Net present value (US\$)			3452.94	1389.06	453.45
Benefit-cost ratio			9.37	4.39	2.10

1. Mng.= management practices only, RBF= raised-bed and furrow only.

Conclusions

The study found that different components of the GPT were partially adopted and modified by the farmers. A key component, i.e. the raised-bed and furrow method of cultivation, was becoming popular amongst farmers. The technology adopter gained through higher grain yield and income, better grain prices, saving of important inputs, including irrigation and female labor force for some tedious operations. It generated consumers' and producers' surplus where the later were the primary beneficiaries. However, the high cost of the implement to make raised-bed and furrows is a major limitation of the technology, therefore, it is important to allocate resources for the design of cost-effective technology that suits the requirements of the farmers. Design of suitable implements, which require minimal efforts in maintaining the raised-bed and furrows, is needed. The study suggests that additional investment in technology transfer activities of GPT will be rewarding in the vertisol region.

1.1.10 Gender Analysis and Participatory Research

By M.C.S. Bantilan, R. Padmaja, D.D. Rohrbach, E.S. Monyo, E.R. Weltztein

Background

ICRISAT is a key member of the systemwide initiative on Participatory Research and Gender Analysis (PRGA). SEPP, the focal point for PRGA from ICRISAT continues to interact, collate and disseminate information to all research staff from and to the PRGA program. SEPP also responds to requests for information from various users regarding gender analysis research at ICRISAT.

Results

Papers presented. A technical consultation on “Gender Roles in Peanut Sector for Household Food Security” held at Kasetsart University, Bangkok, Thailand from 9-12 June 1998 included a resource paper from SEPP titled “Gender Differences in Groundnut Production Technology Evaluation and Choice: ICRISAT Experience and Relevance for Future Technology Development.” The paper demonstrates how gender specific perceptions can yield valuable information about the usefulness of a technology as well as the constraints that hinder adoption (Table 1). User perspectives of technology were closely related to the roles and responsibilities and power relationships between men and women. Women considered occupational hazards as well as workability options and not just the financial analysis of male farmers.

Another resource paper entitled “Participatory Research and Gender Analysis Approach in Agricultural Technology Evaluation: ICRISAT Experience” was presented at the FAO organized expert consultation on “Participatory Research Methods and Gender Database” held at Bangkok in May 1999. The outcome of the consultation was a framework for a local database that would reflect gender differences in local production systems and access to resources and opportunities that would aid in gender responsive planning at all levels. The SEPP database was taken up as a model for building this gender differentiated database at the local level.

Development of research project proposal. A research project proposal on gender entitled “Women in Marginal Areas: Reaping Benefits from SAT Technologies” was developed in 1998 following an earlier brainstorming meeting. The proposal suggests a set of exploratory studies on gender impacts in the SAT with special reference to research on the roles of women in conserving bio-diversity, seed production and natural resource management. A smaller version of the proposal was submitted to the CGIAR Program on Participatory Research and Gender Analysis in response to a call for three year grants for Action Research and Capacity Building for the Application of Gender Analysis and Participatory Approaches to Natural Resource Management. The proposal has been accepted and is among a group of 22 proposals that have been short listed for consideration for funding in 1999/2000. Follow up activities for developing next round of proposal are in progress.

Table 1. Perceptions of men and women farmers on components of groundnut production technologies, Umra, Maharashtra, 1992/93: merits and demerits as cited by men and women.

Component	Merits (Men)	Merits (Women)	Merits (Men)	Merits (Women)
Broadbed & furrow system	Saves labor Improves yield No wastage of water or fertiliser Better water management Aeration to soil	Seed rate is low Weeding is easy Ease of harvesting More yield Soil becomes loose and friable	Requires sprinkler irrigation Requires more cash and manpower	Requires more labor Requires sprinkler irrigation
Dibbling	Requires less seed Even plant population Good germination Good yields	Even plant population Requires less seed More employment for women Good germination	More labor required especially female labor Costly	Tedious and time consuming Painful and back bending
Gypsum application	Pods well formed More yield Soil becomes soft and loose Disease problem partly reduced	Pods well formed More yields Involvement of women increases Shelling is easy because of well formed pods		
Application of micro nutrients	High yields Fungal problem minimized Disease problem partly reduced	Good yields		
Sprinkler irrigation	Saves water and time Requires less labor Easy to operate Uniform irrigation Covers more area Soil becomes soft Good yields	Saves water and time Covers more area Pest and disease problem reduced: pressure of water causes eggs and insects to fall	Costly	Costly.
Seed management	Seed need not be purchased	Employment opportunity increases Select good seed	Requires more care	Additional burden

Component	Merits (Men)	Merits (Women)	Merits (Men)	Merits (Women)
		hence good yields		
General remarks	High yields Increase in income	Good yields Increase in income	More hired labor hence expensive	Expensive

Source: Gender Analysis of Sat Technologies surveys, 1994

1.1.9.1 Technological Innovations in SAT Agriculture and their Impact on the Poor in India and Chad

by M.C.S. Bantilan, D. Parthasarathy, R. Padmaja, J. Ndjeunga, and T.J. Wyatt

Background

Numerous studies have documented the impacts of new agricultural technology on various sectors (eg. farmers, consumers). However, inadequate information is available on how these new technologies impact on the poorest segments, eg. resource-poor farmers with small landholdings located in harsh environments. SEPP is conducting a series of activities aimed at delineating “poverty areas” in the SAT and then examining the impacts of technological change specifically on people living in those areas.

Results

Papers presented. A scientific paper entitled “Enhancing research-poverty linkages: ICRISAT Experience” was presented at an international workshop on “Assessing the impact of agricultural research on poverty alleviation” held at San Jose, Costa Rica from 14-16 September 1999. This paper presents the experience at ICRISAT in assessing its impact on the poor and establishing the linkage between new technologies and welfare changes in the SAT region. SEPP represented ICRISAT in the postworkshop meeting together with the participation of CIAT staff, international steering committee members, and stakeholder representatives. The post workshop meeting included a summary and assessment of the event, the presentation of possible program options that were collected over the previous two and a half days, and discussion of options that resulted in some consensus about "next steps."

Development of research project proposal. SEPP has developed a project proposal titled “Technological Innovations in SAT Agriculture and its Impact on Poverty in India and Chad” to measure the impact of technological innovations on the poor in water limited environments of the SAT. The proposal is one of the 14 case studies included in the CGIAR-IAEG poverty impacts study. The proposal has drawn keen interest among several donors during the CGIAR-IAEG Design Workshop with the IAEG Steering Committee and the donor community held in May 1999 in Washington D.C. Funding has been assured but we are still awaiting a go signal from the Steering Committee.

The project has been planned in two phases. Phase 1 includes project proposal finalization and participation in a design workshop held in Washington D.C. in May 1999. The workshop brought case study leaders from the various CGIAR centers together with external advisors and a number of CGIAR donor representatives. In addition to agreeing on best practice methods for quantitative impact assessment, the workshop participants also agreed on the need for complementary institutional and social analysis of the context in which new technologies are released and adopted. This is needed to better understand agricultural research impacts in the context of broader definitions of poverty and social

outcomes including empowerment, and how research might be better targeted or integrated within the broader context of social development for sustainable rural livelihoods.

The project aims to use methodologies to identify and delineate the location and dynamics of the poor in this environment and determine the share of benefits gained by the poor holdings from R&D generated technology innovations. The delineation of poverty locations will take into account the socio-economic characteristics of the poor, and the agro-ecological conditions in which they eke out their livelihoods. This delineation will provide a better capacity for targeting research programs that will benefit the poor. The actual share and nature of benefits gained by the poor farmers and consumers from the research products generated over 25 years of ICRISAT/NARS partnerships is to be determined. The study aims to highlight the importance of doing research in the harsher environments with poor natural resource endowments, where the poorest of the poor are believed to be. Eventually, it is hoped that the study will contribute to the process of research priority setting, and better targeting of technologies.

Important progress has been made in several areas in the measurement of impact of technology change in poverty alleviation. Approaches to project implementation, methods of data analysis and required data sets have been identified.

Typologies for poverty analysis. Household typologies using key parameters related to household assets, access and human capital which is key to analysis of household poverty impacts is being developed. Patterns of adoption across different levels of marginality also need scrutiny. GIS tools are utilized in examining patterns of the relationship between rates of adoption and levels of marginality. Analysis includes the linkages between technology traits and levels of adoption by region. This analysis is expected to reveal preferred traits and give insights into benefits accruing to households brought about by adoption of a trait-related technology. Information on reasons for non-adoption is also useful in examining the causes for negative or zero impact on households.

Database for SAT poverty analysis. Assessment and development of a database for the poverty impacts study has commenced. The following datasets have been identified and information collected. The description of the datasets is as follows:

Agro-climatic database. The database consists of data relating to soil quality, temperature, rainfall, length of growing period, and potential evapotranspiration.

Adoption database. The database includes data on the following - household types (land holding, irrigation, type of soil, education, % of coarse grains and pulses to gross cropped area), yield, productivity, proportion of yield retained for consumption, income increase (where available).

Baseline datasets. A preliminary assessment of available baseline data has been made. These include data sources which provide information at various levels of aggregation on indicators that have been identified. The data sources include:

- Village level (primary data): Adoption rate of ICRISAT/NARS technologies, yield improvements, increase in income, employment.

- Block level (secondary data): Demographic data - education, occupation, population density, percentage of scheduled castes and scheduled tribes to total population, literacy rates, proportion of agricultural labour, housing and household amenities.
- District level (secondary data): Percentage of area under coarse grains to gross cropped area, percentage of area under HYV for coarse grains to total coarse grains area (already available with GIS), gross irrigated area, gross cropped area, agricultural wages, total number of markets, road length, ownership of assets (land, farm machinery).
- State and national level (secondary data, e.g. NSS surveys of India): This type of data allows measurement of poverty indicators measured by headcount index, poverty gap index, and Gini coefficient using consumption and expenditure data, average total expenditure, agricultural wages, use of traditional sources of energy/fuel.

Pilot survey. A pilot survey was conducted as part of project development. The objective was to make a preliminary assessment of the issues, linkages and survey approaches with reference to the following set of questions:

- What are the dynamics of the welfare changes among rural poor households as a result of improvement in crop yields, income and other social indicators?
- What is the process whereby technology adoption translates into benefit flows which alleviate poverty and in what dimensions?
- What are the mechanisms and elements of the new sustainable system of agriculture that have been put in place as a result of technology adoption?

In attempting to find the means of answering these broad questions, we also seek to resolve specific methodological issues like: what are the most appropriate indicators for measuring poverty reduction? what are the enabling conditions for adoption and benefits to occur c) are there any intervening variables, which can help explain the process of poverty alleviation? d) do benefits flow to social categories equally? what explains the welfare changes along different dimensions occurring at different points of time? Are changes due to technology adoption restricted to a shorter time period, or to one aspect of the cropping system only? or are these affecting the entire cropping system leading to long term sustainable benefit flows?

Based essentially on a number of focused group interviews with different social/occupational groups, we found that there are direct as well as indirect ways in which technology adoption has contributed to welfare changes. Rather than follow a particular path, a stream of benefits seems to flow as a result of technology adoption. Taking the groundnut production technology (GPT) as an example, GPT adoption leads to changes in cultivation practices and generations of assets, among others, which lead to other changes in the agricultural system.

It is evident from the analysis of “before and after” situations that a large number of welfare changes have occurred. This is summarized as follows:

1. Changes in cropping pattern, i.e. more diversified cropping system and more diversified basket of commodities produced
2. More land under cultivation due to increased capacity to invest and more crop options
3. Increased area under cultivation during post-rainy and summer seasons, mainly observed for groundnut and chickpea
4. More area under irrigation with the availability of sprinklers and pumpsets
5. Reduced dependence on risky crops and crops requiring more inputs
6. Increase in yields
7. Increase in income and profits
8. Generation of permanent and semi-permanent assets -- land, livestock, pumpsets, sprinklers, etc.
9. Changes in the landholding pattern, i.e. some agricultural laborers bought land while marginal farmers also increase their landholding
10. Increase in wages among agricultural workers
11. Increased availability of employment throughout the year
12. Improved choice of work and workplace
13. Improvement in nutrition with increased consumption of pulses and oils and wider basket of commodities consumed by farmers and agricultural laborers
14. Reduced spending on food items
15. Increased capacity to support non-working family dependents
16. Reduction of indebtedness
17. Easier availability of credit
18. Improved visibility of the village, i.e. ICRISAT technology adoption bringing prosperity to a village has attracted other government programs to the village.

Some conclusions drawn from the pilot survey are:

1. GPT adoption has contributed directly to increase in income and yields
2. Stability of the cropping system was enhanced
3. Crop diversification led to improved food availability, food security and improved nutrition
4. Assets acquired for GPT are also used for other crops, and enabled cultivation in other seasons
5. Initial benefits in the form of higher profits were reinvested in order to obtain long term benefits and stability to farming system
6. Stability of the farming system increases the freedom of farmers to take decisions on cropping patterns, e.g., cash vs subsistence crops, market vs subsistence orientation, investing in production vs investing in education, housing, household assets, etc.
7. Better labor conditions: employment opportunities for women have gone up; labor out-migration has been replaced by in-migration
8. Credit rating has gone up
9. Increased capacity to perform traditional cultural activities (festivals, pilgrimages) and fulfil social obligations (marriage of children and hospitality to household and community guests)
10. Government programs target villages after its “visibility” improved after technology adoption and resultant impact
11. Improvement in health, sanitation, housing, and community facilities

12. Empowerment, i.e. improvement in self-esteem, confidence and ability to innovate. Also reflected in increased choice of crops for cultivation, choice of investments, access to credit and information
13. Reduction in the social distance between groups of different social status; reduction of the feeling of isolation within the community as well as with respect to the outside world. This implies that the community has become more socially inclusive, with greater interaction between members of different social categories.

Summer training. Two posters related to different aspects of the poverty impacts project were developed at a workshop held for summer trainees. The first poster was based on a literature survey on research, technology adoption and poverty alleviation (Fig. 1). The poster related poverty issues using path analysis, and linked macro and micro data to develop operational definitions for poverty indicators. The poster was based on a report detailing the conceptual framework underlying the technology adoption-poverty alleviation linkages using illustrations from the literature.

A second poster focused on development of a typology of households based on analysis of baseline data sets of India (NSS data). The development of household typologies started with the asset base. In particular, farm size variations in relation to percent operated area and yield were taken as the basis for developing this typology. This exercise was carried out for selected districts of Rajasthan where adoption surveys were conducted for pearl millet. A report on the results from this exercise was also presented.

1.2 Adoption case studies providing objective documentation of the uptake of ICRISAT/NARS research investments

1.2.1 *Adoption of Improved Pearl Millet Cultivars in India: A Case Study*

By M.C.S. Bantilan, Y.M. Rao, V.K. Chopde, S. Gupta, S. Haldar, K.N. Rai, S.D. Singh, C. Ramasamy, S. Elongovan, R. Pethani, and U.K. Deb

Background

Pearl millet is an important food crop and source of feed and fodder for milch animals in India. Planted area is 10.11 million ha and production is 7.15 million tons of grain (1994-95). Though the area under pearl millet has declined during the last three decades compared to its 1966 level of 12.24 m ha, production has increased (4.47 m tons) due to considerable increases in productivity. Rajasthan ranks first in India in terms of area (4.96 m ha), followed by Maharashtra (1.77 m ha), Gujarat (1.2 m ha), Uttar Pradesh (0.76 m ha), Haryana (0.58 m ha) and Tamil Nadu (0.21 m ha).

ICRISAT in collaboration with NARS partners has developed many improved cultivars. MH 179, ICTP 8203, WC-C 75, ICMH 356 are the most popular among the releases. NARS public and private seed companies have also developed cultivars using ICRISAT materials, for example MH 169, HHB 67, JKBH 26, Nandi 18, Eknath 301, among others. These cultivars are high yielding, resistant to diseases and pests, and tolerant of drought. Farmers have widely adopted these cultivars in many parts of India, but large areas, especially in the desert margins of Rajasthan, are still under local cultivars. This study was conducted to track the adoption of these cultivars in farmers' field. The specific objectives of the study were:

- To understand the trends in adoption of improved pearl millet cultivars in selected states
- To estimate cultivar specific adoption of improved pearl millet cultivars in different agro-climatic zones
- To identify factors (biotic, abiotic and socioeconomic) influencing adoption
- To draw lessons on cultivar adoption and policy implications for future research.

Methodology

A reconnaissance survey was first conducted to gain preliminary insights on adoption of production technologies and constraints faced by pearl millet farmers. This was followed by the collection of secondary data and discussions with officials in Directorate of Agriculture, scientists from ICRISAT, the Indian Council of Agricultural Research (ICAR) and other research institutes, and representatives from the private seed sector.

This preliminary work was undertaken to provide a basis for an in-depth on-farm adoption study. A sample of representative pearl millet growers was selected in the top 5 pearl millet producing states of India. A total of 1683 farmers from 154 villages of 77 blocks in 39 districts from Maharashtra, Rajasthan, Gujarat, Haryana and Tamil Nadu were selected. Details are given in Table 1.

Improved pearl millet cultivars were categorized into five groups: ICRISAT cultivars, NARS-public sector cultivars with ICRISAT materials, NARS-private cultivars with ICRISAT materials, NARS-public sector cultivars without ICRISAT materials; and NARS-private sector cultivars without ICRISAT materials. Some farmers were not able to name the variety but were sure it was an improved cultivar. Such cultivars were labeled “improved but unidentified”.

Results and Discussion

Trends in adoption of improved cultivars. Trends in adoption of different cultivars in Maharashtra are presented in Figure 1. Figure 2 shows the rate of adoption of different types of improved cultivars in Maharashtra, Rajasthan, Gujarat, Haryana, and Tamil Nadu.

Maharashtra. The area under HYV pearl millet reached 94% in 1994. Adoption of ICRISAT cultivars (ICTP 8203, WC-C 75, and MH 179) has increased from 35% in 1990 to 47% in 1992, slightly declining to 36% in 1994. The area under ICTP 8203 increased to 43% in 1992 compared to 29% in 1990 but declined to 30% in 1994. The area under WC-C 75 and MH 179 was reported to have declined due to non-availability of seeds as well as replacement by newer varieties.

The adoption of NARS-public cultivars (BK 560, BJ 104, MH 169, and RHRBH 8609) declined from 24% in 1990 to 14% in 1994. The area under BK 560 and BJ 104 is declining due to their susceptibility to downy mildew; while the area under MH 169 and RHBH 8609 has increased. The average area under NARS-public cultivars during 1990-94 period is 19%, of which 4% area is covered with hybrids developed using ICRISAT materials.

The adoption of private cultivars (MLBH 104, MLBH 267, and others from Vijay, Nath, Paras, Mahyco, Pro-agro, Nandi, and Pioneer seed companies) increased from 19% in 1990 to 44% in 1994. The average area under private sector cultivars during 1990-94 was 31% of which 23% area is covered with hybrids developed using ICRISAT materials.

The area under local cultivars declined from 22% in 1990 to 6% in 1994 due to their low yield potentials and long duration.

Rajasthan. The uptake of improved pearl millet cultivars in eastern Rajasthan increased from 44% in 1992 to 56% in 1996. BK 560, a public sector cultivar, ranks first among improved cultivars and occupied 20% and 18% area in 1992 and 1996, respectively. The adoption of another public sector cultivar, HHB 67, increased from 1% in 1992 to 2% in 1996. MH 179, an ICRISAT-developed cultivar, increased from 3% in 1992 to 9% in 1996. Eknath, a private hybrid based on ICRISAT germplasm materials, increased to 4% in 1996, from less than 1% in 1992. A general major shift in adoption occurred in 1994, when many private seed companies began introducing their hybrids into the market.

The share of local or desi pearl millet cultivars in farmers' fields was around 48%.

Zonal adoption. Two zones in the study area in Rajasthan were identified based on rainfall pattern, soil type, and temperature: low rainfall zone or zone A (less than 500 mm rainfall) and high rainfall zone or zone B (rainfall 500 mm or more). Zone A includes the districts of Churu, Nagaur and Sikar while zone B includes Ajmer, Alwar, Bharatpur and Jaipur districts.

The adoption of improved pearl millet cultivars was higher in zone B (58%) than in zone A (48%). It was also observed that despite a government ban on cultivation of BK 560 due to its high susceptibility to downy mildew, it remained popular in zone A (27%). On the other hand, its adoption declined drastically to 2% in zone B. This observation is explained by better access to newer seeds, especially from the private sector in zone B. Farmers in zone A tended to continue to depend on their own seeds. MH 179 occupied about 7% area in both zones. WC-C 75, an ICRISAT cultivar, was more popular in zone B (5%) than in zone A (less than 2%). Unidentified improved cultivars cover 4% area in zone A and 13% in zone B. Local or desi cultivars continued to be grown although their share is declining in both zones: 52% area in zone A and 42% area in zone B.

A positive relationship between rainfall levels and grain yield was noted. On-farm yields in the high rainfall zone were observed to be 2.6 times higher than in the low rainfall zone.

Gujarat. The rate of adoption of improved technologies in Gujarat is high. Adoption rates were 95% in 1990, increasing to 99% in 1995. During this period, the adoption of ICRISAT-developed cultivars (ICTP 8203 and MH 179) increased from 26% to 31% for rainy season cultivation and from 18 to 27% for summer cultivation. In both seasons, the area grown increased to 30% in 1995 from 23% in 1990. The area under MH 179 increased slightly from 23% in 1990 to 26% in 1995.

Between 1990 and 1995, the adoption of NARS-public cultivars went down from 54% to 32% in the rainy season and from 72% to 51% in the summer season. In both seasons, the area declined from 61% in 1990 to 39% in 1995. In particular, the area under three earlier releases, BK 560, BJ 104 and CJ 104, decreased due to their susceptibility to downy mildew. At the same time, the area under NARS-public cultivars based on ICRISAT materials increased from 12% in 1990 to 34% in 1995. The area under NARS-public cultivars without ICRISAT material declined from 49% in 1990 to 5% in 1995.

The uptake of hybrids from the private sector (Nandi 18, Navbharat, Vijay, Prashanth, Deepak, Paras, Mahyco, Pro-agro, and Pioneer) has increased in both seasons. Area under these cultivars increased from 12% to 35% in the rainy season and 10% to 23% in the summer season. Area under pearl millet hybrids developed by private seed companies based on ICRISAT germplasm materials increased from 5% in 1990 to 18% in 1995.

There was a notable decline of area under local cultivars in Gujarat, recorded at 5% in 1990, declining further to less than 1% in 1995, due primarily to their low yields and long duration.

Haryana. Adoption of improved pearl millet cultivars increased in Haryana from 44% in 1992 to 86% in 1996. The percentage of farmers adopting improved pearl millet has also increased from 56% in 1992 to 86% in 1996. Among the selected districts, adoption of improved cultivars was highest (100%) in Jind district, followed by Hisar (94%) and Rewari (86%). The lowest (76%) was observed in Bhiwani district. HHB 67, a public sector hybrid developed by using ICRISAT material, is widely adopted in the state. It covered about 21% of pearl millet area in 1992, increasing to 38% in 1996. It ranks first among the adopted pearl millet hybrids in the state. Nandi 18, an ICRISAT derived private sector cultivar, ranks 2nd and its share increased from 9% in 1992 to 16% in 1996. Pro-agro 7701, a private sector cultivar, stood 3rd in 1996 though it had much smaller share than HHB 67 and Nandi 18 in 1992. Adoption of ICRISAT cultivar MH 179 was about 2% throughout the study period. Adoption of cultivars like KH 322, PG 5834, Nandi 18 has increased over the 5 year period. Local or desi cultivars declined sharply, from 56% in 1992 to 14% in 1996.

Tamil Nadu. NARS private cultivars are dominant in Tamil Nadu. ICRISAT cultivars (ICMS 7703, ICMV 221, WC-C75) occupied second place with 23% of area, NARS-public cultivars occupied 12% area, and local varieties 23%. The remaining area was under private cultivars. WC-C 75 covers about half the area under ICRISAT cultivars. Pioneer (hybrid) dominates two-thirds of the total area under private sector cultivars. The leading cultivars among NARS public were CO 7 and KM 2.

Preferred traits. Farmers were asked to rank the traits they like in the improved cultivars they are growing. High grain yield ranked first across the states (Table 2). Fodder yield ranked 2nd in Maharashtra, Haryana, and Gujarat. Other preferred traits were short duration, disease resistance, drought resistance, taste, and bigger grain size.

Constraints faced by farmers. Farmers were also asked to cite and rank the constraints they faced in growing improved pearl millet cultivars. Results are given in Table 2. According to them non availability of seed, low fodder yield of the existing cultivars, lack of awareness, high water requirement for improved cultivars, poor extension service, and poor grain and fodder quality are the main constraints.

Conclusions

Improved pearl millet cultivars (either released by the public or private sectors) based on ICRISAT germplasm materials were found to dominate in the pearl millet growing zones of India. The share of private hybrids relative to the total pearl millet area is increasing. Qualitative data gathered during the on-farm surveys indicate that future research for development of new pearl millet cultivars should focus on the following traits -- dual purpose (grain and fodder) especially for the drought-prone areas where pearl millet is best adapted, short duration to escape drought, maintenance research for downy mildew resistance, drought resistance, bold grain and better taste. Increasing adoption levels and production efficiency will be facilitated by institutional arrangements involving both public and private sectors for seed multiplication and timely distribution.

Table 1. Number of sample farms in different states of India.

State	Districts	Blocks	Villages	No. of farmers
Maharashtra	9	18	36	360
Rajasthan	7	14	28	331
Gujarat	11	21	42	419
Haryana	5	10	20	237
Tamil Nadu	7	14	28	336

Table 2. Farmer-preferred traits of improved pearl millet cultivars in selected states of India.

Trait	Ranks provided by the farmers of				
	Maharashtra	Rajasthan	Gujarat	Haryana	Tamil Nadu
High grain yield	1	1	1	1	1
High fodder yield	2	4	2	2	
Short duration		2	6	3	
Disease resistance	3	5	3	4	3
Drought resistance	2	3	5	5	2
Better taste	4	7	4		
Large grain size	5	6			4

Table 3. Constraints to improved pearl millet cultivars faced by farmers in India.

Trait	Ranks provided by the farmers of			
	Maharashtra	Rajasthan	Gujarat	Haryana
Non availability of seed	1	2		
Low fodder yield		1		
Lack of awareness	2	3		
High water requirement	4	4		2
Poor extension	3		2	
Poor grain quality		5	1	3
Poor fodder quality	5	1	3	1

1.1.2 Adoption of Improved Sorghum Cultivars and its Determinants in India

By M.C.S. Bantilan, Y.M. Rao, V.K. Chopde, G.D.N. Rao, U.K. Deb and S. Shomo

Background

Public and private sorghum research in India, often in partnership with ICRISAT, has developed about 182 improved sorghum cultivars. Improved cultivars, particularly the rainy season hybrids, have many desirable traits such as higher productivity, wider adaptability, short duration and stature, response to applied nutrients, effective components in IPM and effective seed production support from public and private sectors. However, the rate of adoption of improved sorghum cultivars in India is comparatively slower than improved cultivars of other crops. For example, the first sorghum hybrid, CSH1, was released in India in 1964 while the first rice high yielding variety in India, IR8, was released in 1966. But the spread of HYV rice and wheat was much faster than improved sorghum. In 1993-94, only 53% of the total sorghum area was under improved cultivars while 67% and 88% respectively of total rice and wheat area was under HYVs (Fertilizer Statistics 1996-97). The present study tries to quantify the extent of adoption of different improved sorghum cultivars and to identify the factors responsible for adoption.

Methodology

Three states--Karnataka, Maharashtra and Andhra Pradesh—were selected for the study. By using the secondary data, all sorghum-growing districts were ranked based on average sorghum area and production for the period 1990-91 to 1994-95. District data were sorted according to kharif sorghum area. Fifteen major kharif sorghum-producing districts were identified in the three target states. Primary data collected from 46 Focus Group Meetings (FGM) were used to verify the hypotheses.

Three blocks were selected from each district, representing high, medium, low intensity of area under sorghum. It was ensured that the selected blocks were good representatives of the district. One village was chosen in each blocks for conducting FGM. The village was selected by the concerned agricultural officer from each block. Around 10-15 sorghum growing farmers belongs to different farm size groups participated in the FGMs.

To quantify the trends in adoption of different cultivars in India, a Rapid Appraisal technique was followed. In this technique specialists working in seed agencies, as well as staff from the Directorate of Agriculture of different states, extension staff from the Training and Visit offices and private seed companies were interviewed. In these interviews, their perceptions were obtained on popularity (including ranking) of different cultivars, and likely percentage share of each popular cultivar to the total HYV area.

Results and Discussion

The area under rainy season sorghum is declining in all three states. The area under post-rainy season sorghum is also declining in most places. The area under improved sorghum cultivars is increasing. The spread of different improved sorghum cultivars varied among states and districts. Hybrids were more popular than improved varieties in all regions due to higher yield. Temporal and spatial variation exists in the extent of cultivation of different sorghum cultivars. In 1997-98, CSH 5, CSH 9, CSH 14, MSH 51,

JKSH 22 were popular kharif sorghum cultivars in Karnataka, Maharashtra, Andhra Pradesh (Table 1). But in rabi, Maldandi (M-35-1) covers more than 90% area. The initial adoption of CSH 1 was evident until the 1980s, as is the subsequent adoption of CSH 5, CSH6, CSH 9 in the early 1990s. At present MSH 51, CSH14 and other private hybrids (JKSH 22, Pro Agro, ITC) are grown to a significant extent. JKSH 22 provides 15-20% higher yield than other hybrids. This is the underlying reason for its increasing popularity. Pro Agro, ITC Zeneca, Pioneer, Hindustan Lever, and other private seeds are sold. Adoption of ICRISAT varieties is negligible. However, hybrids developed from ICRISAT germplasm such as JKSH 22 are gaining popularity (Tables 1 and 2).

The major constraint to sorghum cultivation, as reported by the farmers, is grain mold. Grain mold resistant cultivars would be rapidly and widely adopted. The reasons for declining rainy season sorghum area are low market price, problems of grain mold and shoot fly, switching over to other commercial crops, and erratic rainfall. The preferred traits among farmers are high grain and fodder yield, resistance to pests and diseases (particularly grain mold and shoot fly), bold grain size and better taste. Farmers prefer short and medium duration varieties to accommodate two crops in a year. Constraints to sorghum production are prolonged drought at critical stages of crop growth, shoot fly and grain mold, and low profitability (Table 3).

Conclusions

For kharif sorghum, research should focus on developing grain mold resistant germplasm materials and cultivars. ICRISAT should focus on developing new cultivars which have high grain yield, fodder yield, short duration, and resistance to pests and diseases, particularly grain mold and shoot fly. Extension of knowledge through on-farm demonstrations and through extension services will enhance the adoption of ICRISAT varieties.

Table 1. Area ('000 ha) under popular sorghum cultivars in India, 1966-93.

Cultivar	1966	1971	1976	1981	1986	1991	1993
CSH 1	190.5	694.3	968.8				
CSH 5			1453.2	1941.0	2200.0		
CSH 6				1941.0	2200.0		
CSH 9					1100.0	5420.8	4051.8
MSH 51						1016.4	1688.3
JKSH 22							540.2
Other improved						338.8	472.7
All improved	190.5	694.3	2422.0	3882.0	5500.0	6776.0	6753.0
Local	17809.5	16082.7	13350.0	12717.0	10448.0	5583.8	6128.7
Total	18000.0	16777.0	15772.0	16599.0	15948.0	12359.8	12881.7

Source: U.K. Deb and M.C.S. Bantilan, 1999.

1.2 Socioeconomic and Institutional Constraints to Adoption of Vertisol Technology Identified

by M.C.S. Bantilan, P.K. Joshi, S.P. Wani, P. Pathak, T.J. Rego, A. Ramakrishna, and G.D.N. Rao

Background

The rainfed semi-arid tropics (SAT) faces two major constraints: water and nutrient stress, and degradation of natural resources. These problems are pervasive due to lack of opportunities to cultivate two crops a year. Crop intensification was considered to be the most effective means to alleviate these constraints. A technology package was designed by ICRISAT in partnership with NARS in India, which was suited for about 12 million ha of Vertisol in India. This package is popularly known as Vertisol technology and has eight components: (i) summer cultivation, (ii) improved drainage (using the broad-bed and furrow method), (iii) dry seeding, (iv) appropriate crops and cropping patterns, (v) improved varieties, (vi) moderate amount of fertilizers, (vii) placement of seed and fertilizers, and (viii) plant protection measures.

A study was conducted to assess the adoption pattern of different components of vertisol technology and to quantify the benefits of adopting vertisol technology in the semi-arid tropics of India. Socioeconomic and institutional constraints to adoption of Vertisol Technology were also identified.

Methodology

Reconnaissance surveys using Rapid Rural Appraisal (RRA) methods were carried out in the Vertisol areas to understand farmers' perceptions of the components of the technology in a watershed framework. Later, a detailed formal survey covering 500 farmers was conducted through personal interviews. These surveys were undertaken in: (i) low rainfall areas (Medak, Sholapur and Gulbarga districts), (ii) medium rainfall regions (Nagpur, Akola, Buldhana, Panchmahals districts), and (iii) high rainfall regions (Raisen and Indore districts). Three approaches were combined together for this study: (i) Cluster analysis to delineate adoption of different vertisol technology options, (ii) Principal component analysis to assess adoption pattern and (iii) Farmers' perceptions of benefits of different technology options. For cluster analysis, three clusters were made according to rainfall in the Vertisol areas -- low rainfall area (<750 mm), medium rainfall area (750-950 mm), and high rainfall area (>950 mm)

Results and Discussion

The Vertisol technology as a full package was not adopted, but different components were widely adopted by different groups of farmers at different locations. Among important components adopted by farmers were improved varieties, application of fertilizers and pesticides, use of spray equipment, and appropriate placement of seed and fertilizer.

One of the most important components of the technology package - the broad bed and furrow, more commonly known as BBF (a system of land preparation consisting of broad beds alternating with furrows designed to improve surface drainage and avoid water logging during the rainy season) - was discontinued by farmers at all locations. Various factors were involved in this rejection:

- Farmers reverted back to using traditional methods to drain excess water or made furrows between rows during cultivation primarily because the Tropicultor (an implement especially designed to make BBF) was expensive and difficult to operate.
- Farmers indicated that if BBF must be constructed each year, the returns do not justify the labor expense unless more profitable subsistence crops or cash crops (vegetables, oilseeds) were grown.
- Maintenance is necessary and expensive since heavy rains invariably damaged the beds.
- In areas where traditional post-rainy sorghum was grown, farmers did not face the problem of excess water and water logging in the fields. Under such situations, farmers felt that BBF were not required.

The following constraints to the adoption of Vertisol technology were identified. Unavailability of bullocks and appropriate implements and insufficient cash were major constraints faced by small and marginal farmers. Low adoption (<20%) of dry seeding was associated with high risk, less marginal rate of returns, and more weed problems. Broad-bed and furrow was not popular among farmers due to unavailability of proper implements, no visible marginal rate of returns on investment, and lack of knowledge.

Management of dry seeding needs greater attention. Farmers reported three major risk related constraints for dry seeding: unassured rainfall, seed damage during high or low rainfall years, and problem of weeds. Improved agronomic and management practices may minimize these risks. Another problem related to dry seeding is that some crops are not suitable for this technology option. For example, soybean which is the most important crop in the high rainfall regions, cannot be grown following dry seeding.

There is a need to develop appropriate length of different crop varieties. In low rainfall regions, intercropping of more than one crop having different periods of maturity will increase the efficiency of rainwater use and productivity of available resources. In medium and high rainfall regions, short duration varieties of different crops for both seasons will facilitate increase in cropping intensity.

Conclusions

The above results highlighted two issues for successful technology generation: (1) targeting the technology appropriately and (2) consideration of economic feasibility within existing cropping systems. A summary of the benefits of the Vertisol technology and constraints to its adoption are presented in Table 1.

1.4 On-the-job and Summer Training Programs

By M.C.S. Bantilan, N.P. Rajasekharan, P.Parthasarathy Rao, and N.V.N. Chari

Background

SEPP initiated a summer training program in 1999. The objectives of the program are to:

- Bring awareness on research opportunities in socioeconomics and policy at ICRISAT among students in leading universities with strong agricultural economics programs
- Assist students in pursuing higher research goals in agricultural economics and policy
- Disseminate new tools and methodological advances in economics in an organized way
- Utilize talents to carry forward on-going project activities, optimizing available funding resources.

This program commenced with the participation of meritorious students carefully selected from two universities in India. This program is expected to expand to other institutions in India and Zimbabwe in 2000.

Methodology

For 1999, two reputed learning institutions in the field of economics were chosen for the first phase of the SEPP summer training program. Organized presentations were prepared by the SEPP Program Director and Director of Human Resources of ICRISAT and presented at two premier universities in India: Delhi School of Economics in New Delhi and Gokhale Institute of Political Economy in Pune. Highlighted were research opportunities in agricultural economics and policy and facilities available at ICRISAT. Personal interviews were held with students who expressed interest to join the Program and the top seven students were invited for the first session and another two for the second session. The students were provided travel costs, residential accommodation, and a stipend during the period of the training program. Each student was assigned to clearly defined activities of on-going projects, working closely with a major supervisor who provide day-to-day guidance and supervision towards understanding the research methodologies adopted in on-going projects. Additional training sessions were also provided on special topics like geographic information systems, report writing, poster development, seminar presentation, and photography, among others. All trainees were also invited to the regular SEPP Thursday seminar to listen to invited speakers as well as present their own research results.

At the conclusion of the training program, all trainees were encouraged to develop a research report, present a poster and develop a paper for publication in the SEPP working paper series which is to be jointly published by the university and ICRISAT. The 1999 trainees are listed in Table 1.

Conclusions

The Program proved to be highly successful in terms of achieving its objectives. Extension of this summer training program in the year 2000 for two other Institutes viz. Indian Institute of Technology, Mumbai and Indian Institute of Management, Ahmedabad has been proposed. Strong interest of continuing this program with Delhi School of Economics and Gokhale Institute of Political Economy has

also been expressed by officials of these two universities. The same initiative for research and educational institutions in Zimbabwe is currently being explored.

Table 1. List of trainees in SEPP, 1999.

Name	Title of project	Working paper title
Mallika Gupta	Chickpea and pigeonpea outlook	Chickpea and pigeonpea situation and outlook
Harsimran Kaur	REIA Adoption Project	Critical factors influencing adoption of improved pearl millet cultivars in Maharashtra and Gujarat
Sonam Gupta	REIA Adoption Project	Critical factors influencing adoption of improved pearl millet cultivars in Rajasthan and Haryana
Sumit Haldar	VLS review	ICRISAT's village level studies in the semi-arid tropics of India: A review
Rashmi G V	Gender analysis project	Gender analysis and participatory research approaches to technology adoption – evidence from the literature
Sarita Chebbi	Poverty impacts	Examining differential impacts on poverty alleviation
Sangita Ghosh	Poverty impacts	Technology adoption-poverty alleviation linkages: a conceptual framework
Shomo Shrivastav	REIA Adoption Project	Adoption of improved sorghum cultivars and its determinants in India: synthesis of focus group meetings

1.5 Training Modules for Research Evaluation and Impact Assessment Methods

By M.C.S. Bantilan, Jeff S.Davis, Godfrey Lubulwa, Susan McMeniman

Background

The development of these training modules on research evaluation and impact assessment is a collaborative project by ICRISAT and the Australian Centre for International Agricultural Research (ACIAR). This is key component of a longer term collaborative initiative between the two institutions.

Results:

The development of the modules started with a set of lectures prepared for the “Workshop on Research Evaluation” at the University of the Philippines, Los Banos on 30 September to 4 October 1996. Additional modules were based on ICRISAT “Training program on research evaluation and impact assessment (REIA)” conducted for various countries in Africa and Asia. More modules were added during the “Training Workshop on Impact Assessment” held at Kasetsart University, Bangkok, Thailand on 27 – 30 April 1998.

Many people have contributed to the development of training modules. The contribution of the following is noted: Cynthia Bantilan (ICRISAT), Ben Buetre (Bureau of Agricultural Research, Manila), Jeff Davis (Rural Industries Research and Development Corporation), Godfrey Lubulwa (ACIAR), Minda Mangabat (Bureau of Agricultural Statistics, Manila), Susan McMeniman (ACIAR) and Tirso Paris (University of the Philippines at Los Banos).

Modules completed include basic methodology, empirical issues, research evaluation minimum data sets, research costs in project level evaluations, cost analysis, adoption, research lags, probability of success, research spillovers, new products, supply shift assumptions, validity of claims on impact and other methodological issues. Hands-on exercises using research evaluation models have also been developed and piloted in several workshops held in Asia and Africa.

Funding support for the development of the training modules was obtained from ACIAR.

Conclusions

Completion of the training manual is important particularly in strengthening the capacity of NARS partners to conduct impact assessment studies. This facilitates the technical backstop function of ICRISAT as it seeks to undertake joint impact studies with national program partners.

1.6 Integrated Impact Database

by M.C.S. Bantilan, R. Padmaja, and P. Parthasarathy Rao

Background

An integrated impact database was constructed using three primary databases – MTP database, technology inventory database and technology adoption database.

Results

The special features of this integrated database are:

- It is in SQL Server (7.0) with Visual Basic (6.0) as the front end
- It is well organized, validated, placed at a central location, and easily accessible
- Different levels of security are incorporated to ensure safety and originality of the data
- User friendly screens for data entry and modifications
- Easy retrieval of data across databases
- Rapid generation of pre-defined reports across databases

The integrated database contains information on – research theme data sets, funding options (i.e. core/complementary), dates of research inception and release of outputs, levels of adoption, constraints limiting adoption and diffusion of technologies, and key variables influencing adoption or non-adoption. Geo referencing of survey locations by incorporation of latitude and longitude coordinates enable spatial analysis of the data.

The above integrated package is ready for use by all staff with some introductory training on SQL server. For more rigorous usage of the package, advanced knowledge of SQL query language and Visual Basic is needed. Plans are underway to integrate other primary databases including resource management technology options (vertisol technology, watersheds, groundnut production technology) and Village Level Studies (VLS) databases with the above impact database. Secondary databases like the Indian District Level Database, census databases and global databases like FAO, will also be integrated in the future.

Database conversion and integration of the MTP database. The MTP data originally stored as spreadsheets is converted to MS Access files. The converted MTP database has MS Access as back-end and Visual Basic as front-end. All files are stored in relational database management system with all necessary links across different tables established. Data from NBC, EVS, EE, IRR, and TABLE folders of the original MTP 94 database was converted.

The front end screens developed in Visual Basic for information retrieval, updating and modifications include the following: type of constraint or problem and outputs, research domains, expected yield gains and losses due to research, scientist years, economic value of success and net-benefit-cost ratios, adoption ceiling levels and scientist years.

From this package a predefined report on ranking by type of funding (core/complementary) can be generated. Together with the rank, the report also gives information on other economic constraints

like efficiency, equity, internationality, sustainability, composite index, research cost and cumulative cost.

Database conversion and integration of the village level studies (VLS) database. The VLS database originally stored in VAX systems as text files has been transferred to desktop system and initially converted to MS Access and subsequently to SQL database. The database now rests in SEPP (previously it was in ITU) with SQL server as the backend.

Data for 12 VLS villages using nine schedules for the period 1975-85 and 1989-90 was converted to SQL database. Front end screens in Visual Basic for information retrieval have been developed. The data for all nine schedules has been integrated but necessary links across different tables are yet to be established. Front end screens for data entry, modifications and updates have also been completed.

Pre-defined reports can be generated for HYV area across different years for different crops on the study villages using this data set. The database is not yet fully operational for use by staff. It is proposed that links be established across all tables within the data set as well as with other databases like the integrated impact database.

SEPP publications database. This database is currently under construction. The existing database in MS Word is converted to SQL database. This database gives information on the type of publication, year of publication, authors, reviewers, processing date of the publication, and status of the publication (i.e. published, under review), and order code, if any.

For information retrieval, a front end screen in Active Server Pages (ASP) which comes with Internet Explorer is being developed. Data inputting, modifications and editing is planned through a screen developed in Visual Basic. Upon completion of this database, it is planned to be placed in the SEPP Home Page (intranet and internet) for a wider audience.

1.2.3 Adoption of improved Groundnut varieties in India

By M.C.S. Bantilan, S.N. Nigam, Y.M. Rao, V.K. Chopde, G.D.N. Rao, U.K. Deb

Background

India is the largest producer of groundnut in the world. About 88% of groundnut area and production in India is concentrated in only in five states: Andhra Pradesh, Gujarat, Karnataka, Tamilnadu and Maharashtra. About 83% of total groundnut area is grown in rainy season and the rest 17% area cultivated in post rainy season. Genetic Enhancement Division of ICRISAT in collaboration with NARS partners has developed many improved groundnut varieties. Among the releases ICGS 11, 21, 44, 49 and 76 are important varieties. These varieties are high yielding, resistant to diseases and pests, and tolerant to drought. NARS public and private seed companies also have developed groundnut varieties such as TMV 2, SB 11, GG 2, JL 24, TAG 24, TG 26, Kopargaon and Khandawa. Farmers have adopted these varieties in a large extent in major groundnut growing states but local varieties are still dominant in many parts of India. This study track the adoption of improved groundnut varieties in farmers' field of Andhra Pradesh and Maharashtra, and identifies the factors influencing adoption of new groundnut varieties and constraints to the adoption of improved varieties.

Methodology

Focus Group Meetings (FGM), Baseline Surveys and Case Studies were conducted to obtain the results of this study. For conducting Focus Group Meetings (FGM), five districts of Andhra Pradesh (namely, Mahabubnagar, Kurnool, Anantapur, Nellore and Guntur) and five districts of Maharashtra (Parbhani, Dhule, Kolhapur, Satara and Yavatmal) were selected through cluster analysis. For baseline surveys, three districts in Andhra Pradesh (Anantapur, Chittoor and Prakasam), and three districts in Maharashtra (Nasik, Dhule and Kolhapur) were selected based on the area, production and yield. Case studies were conducted in selected pockets of Andhra Pradesh and Maharashtra where adoption of ICRISAT groundnut varieties is very high. Case studies were conducted to know the factors influencing higher adoption of ICRISAT groundnut varieties in five districts—Guntur and West Godavari in Andhra Pradesh, and Satara, Parbhani and Nanded in Maharashtra. A random sample of 10-12 farmers belonging to small, medium and large farm size groups were selected in each village. Thus, a total of 485 farmers from 45 villages of 11 districts of Andhra Pradesh and Maharashtra were interviewed.

Results

Groundnut Production Technology (GPT): Farmers did not adopting whole package of practices due to lack of proper dissemination, high cost of inputs, poor extension and practical problems in adopting certain components. Majority of the farmers adopted certain components like improved varieties, fungicide application, and plant protection measures. Few farmers adopted the components of micro-nutrients, gypsum, sprinkler irrigation, seed treatment, and balanced fertilizer. None of the sample farmers used broad bed and furrow (BBF) for groundnut cultivation due to high costs of implements required for preparing BBF, draft power and difficulty in maintenance of bed. The other component dibbling the seed is requires more labor than their traditional (drilling) sowing method. So, this technology was not popular in the groundnut growing villages in Andhra Pradesh.

Few farmers in Maharashtra state adopted dibbling method for sowing groundnut. Few farmers also adopted BBF for groundnut cultivation where it was disseminated properly in Maharashtra.

Integrated Pest Management (IPM): It has gained acceptance among the farmers in Guntur district. Major benefits of IPM, as reported by the farmers, are: (a) increased profits due to reduction in cost on pesticides, (b) availability of palatable and nutritious fodder due to low leaf shedding and easy pulling of plants without losing pods in the soil, (c) increased productivity and shelling percentage, and (d) reduced health risks and environmental damage. It is not spreading to the surrounding villages due to lack of group action, proper extension and certain practical difficulties. These constraints need to be addressed for higher acceptance of this technology and create more confidence among the farmers. Extension personnel should visit regularly to the villages for providing guidelines, education and training to the farmers. Supply of improved, pest and disease resistant cultivars and Pheromone traps with good quality lures, NPV and neem based chemicals will create interest among the farmers to adopt this technology.

Adoption of Improved groundnut varieties: TMV 2, JL 24, Kadiri, TPT and ICGS are important varieties adopted by the farmers of Andhra Pradesh. SB 11, GG 2, JL 24, TAG 24, TG 26, TMV 10, Kopargaon, Khandawa, UF-70-103, Karad 4-11, Ghungari, Gujarat 2 are important cultivars adopted by the Maharashtra farmers. Department of Agriculture and State Seeds Development Corporation supplied ICGS cultivars to the farmers. The performance is impressive under irrigated conditions compared to dryland. Due to non-availability of seed, the area under ICGS varieties is less than 2% in Andhra Pradesh and less than 5% in Maharashtra. Estimated area in Andhra Pradesh under groundnut varieties TMV 2, JL 24 and other (Kadiri, TPT and ICGS) are 70%, 20% and 10%, respectively. Estimated area under groundnut varieties SB 11, JL 24, TAG 24 and others in Maharashtra is 60%, 20%, 10% and 10%, respectively. Reasons for low adoption of ICRISAT groundnut varieties in Maharashtra are long duration varieties & non-availability of seeds. ICGS 11, 44, 21, & 49 were observed on farmers' field in locations where technology was disseminated and seeds were made available. In recent years adoption of TAG 24 is increasing in Maharashtra due to short duration & high pod yield characteristics. Adoption of ICGS varieties was high in West Godavari and Guntur districts of Andhra Pradesh. Area under ICGS varieties increased from 12% in 1985 to 100% in 1997 in West Godavari replacing TMV 2. Area under ICRISAT varieties increased from 8% in 1987 to 70% in 1995 and then declined to 64% in 1997 in Guntur district. Adoption of ICGS varieties was high because few farmers of the village produced these varieties for seed. ICGS varieties were adopted during 1989 in Prakasam district. Area decreased from 8% in 1989 to 2% in 1997 due to non-availability of seed. Availability of good quality seed is also a problem. Area under TMV 2 declined from 99% in 1988 to 80% in 1997 in Prakasam district. Easy availability of seed, high yield and higher price of Kadiri helped its expansion upto 18% in 1997 by replacing ICGS varieties and TMV 2. TMV 2 and JL 24 are important varieties adopted by the farmers in Anantapur and Chittoor districts. TMV 2 is widely adopted due to seed availability, drought resistant and yield stability. Area under TMV 2 declined from 100% to 65% in Anantapur and 40% to 29% in Chittoor districts from 1990 to 1997. In the same period, area under JL 24 increased from 1% to 31% in Anantapur and from 60% to 69% in Chittoor districts. JL 24 and Kadiri are replacing TMV 2 due to higher yield, higher price and short duration. Area under ICRISAT varieties was negligible in these districts. Area under summer groundnut is increasing in Dhulia, Satara & Kolhapur districts of Maharashtra whereas it declined in Parbhani & Yavatmal districts. Area under rainy season groundnut is declining in all study districts of Maharashtra.

Cotton, onion, soybean, sugarcane are replacing groundnut. The reasons for declines are erratic & uncertain rains, lower levels of profit compared soybean & pulses, and frequent drought.

Preferred traits

More pod yield (40-50%), pest and disease resistant are important traits liked by Andhra farmers in ICGS varieties. Maharashtra farmers' perception about ICGS varieties include 30% higher pod yield, resistant to disease & pest, bold seed with sweet taste, more oil & shelling percentage. Farmers reported that ICGS varieties are long duration, drought susceptibility and weak pegs. Adoption of ICGS varieties was limited to few villages in Andhra Pradesh. Spread to other areas is constrained due to non-availability of seed and requirement of water for irrigation. Preferred traits for a new groundnut cultivar are more pod yield, short duration, resistant to drought, disease and pest, more shelling and oil percentage. Preferred traits for rainy season groundnut varieties in Maharashtra are medium duration, determinant & sequential flowering, more pod yield, erect & bunch type, and resistant to disease & pest. Short duration, more pod & fodder yield, more oil & shelling percentage, seed viability and resistant to disease & pest are preferred traits in summer season groundnut in Maharashtra.

Production constraints

Important production constraints in groundnut cultivation in Andhra Pradesh are late rains, erratic and uneven distribution of rain, non-availability of drought resistant cultivars, weed population, low plant population due to poor seed quality and low seed rate, unbalanced fertilizer dose, pest and diseases. Major constraints for Maharashtra are lack of quality seed, bad weather condition, frequent drought, high incidence disease & pest and labor shortage. Reasons for low adoption of ICGS varieties are non-availability of seeds, longer duration, seed viability, lack of extension, weak pegs, less multiple ratios.

Conclusions

The main factors influencing adoption of improved groundnut varieties are high yield potential of pod and fodder, timely availability of seed, duration of the crop, irrigation, awareness of the cultivar. ICRISAT should further focus on developing new groundnut varieties which address farmers needs such as high pod and fodder yield potential, short duration, drought resistance, suitable to different agro-climatic conditions, resistant to pest and diseases. Area under ICRISAT groundnut varieties was low (1-5%) in both the states due to non-availability of seed, lack of awareness and long duration. Promotion and extension through NARS, and ensuring timely seed supply will definitely enhance the adoption of ICRISAT varieties in future.

S2: Evaluate Growth Prospects and Opportunities in SAT Agriculture

Team members

A. Hall, H.A. Freeman, T.G. Kelley, S.N. Nigam, P. Parthasarathy Rao, P.K. Joshi, C. Johansen, S. Aradhyula, Ashok Gulati, and G. Kumar

Goals

Improve the ultimate relevance of research and policy formulation by having sufficient forecasting knowledge to target current activities to the priorities which will be important in the future.

Intermediate goals

Gain a clear vision of trends, constraints and opportunities which will face the SAT over the coming decades.

Purposes

The socio-economic environment and pattern of utilization of natural resources is constantly evolving in the SAT, as elsewhere. Even as some existing production systems retreat, new policies, improved technologies, the introduction of new crops, and infrastructural changes open opportunities for new sources of farm income, as well as new risks. Such changes have consequences for regional food supplies and prices, and in some cases, for the natural resource base (e.g., irrigation development). To remain relevant, strategic research conducted by IARCs like ICRISAT must be forward-looking, since its impacts lie years into the future.

Outputs

Details are provided in the following pages. Progress is reported under five sections:

- 2.1 Situation and outlook reports
- 2.2 Changes in cropping patterns in the Indian SAT
- 2.3 Development of the Indian district-level database
- 2.4 Rainfed Agriculture Typology for India constructed and characterized
- 2.5 Critical review of agricultural trade and input price policy in India
- 2.6 Impact of agricultural policy reforms in India
- 2.7 Final report on Sustainable Rainfed Agriculture Research and Development in India (Module I).

2.1 Situation and outlook reports

2.1.1 The World Groundnut Economy: Facts, Trends, and Outlook

By H.A. Freeman, T.G. Kelley, S.N. Nigam, P. Subrahmanyam, P. Parthasarathy Rao

Background

Groundnut is one of the principal oil seeds in the world. The nuts are eaten in a variety of forms or crushed to provide vegetable oil for human consumption and protein rich meal for livestock feed. The haulms are an important source of fodder in developing countries. In addition, the crop helps improve soil fertility through biological nitrogen fixation and can thus contribute to improvements in the sustainability of cropping systems. Developing countries account for almost 95% of global production, and Asia about 70%. The major producers of groundnut are India, China, and the USA, which together account for two-thirds of global output. Other important producers are Nigeria, Senegal, Sudan, and Argentina.

Groundnut is largely a smallholder crop, grown under rainfed conditions in semi-arid areas. It is simultaneously a food and cash crop providing smallholder families with dietary protein and high grade fat as well as cash income from sale in local markets. The crop is also grown on a commercial scale using high levels of inputs. Groundnut oil, meal, and other products are extensively traded, particularly in domestic markets.

The objective of the study was to provide an overview of trends and outlook for groundnut production, utilization, and trade. It examines constraints to groundnut production, discusses domestic, international policy and technological issues that influence supply and demand and analyzes future prospect for the crop.

Methodology

Data for the study were obtained from various sources including FAO data files, United States Department of Agriculture Policy papers, and various reports from the FAO, World Bank, and IMF. Trend lines were estimated using a semi-logarithmic form for which the coefficient on the time trend is the growth rate of the variable on interest.

Results

Groundnut is currently grown on 23 million ha worldwide, up from 19 million ha in 1979-81. During the past two decades, groundnut area has expanded in Africa and Asia, increased marginally in developed countries, and declined sharply in Latin America and the Caribbean. Global yields currently average 1.3 t ha⁻¹, about 30% higher than in 1979-81. However, this overall picture conceals large differences between low-input traditional systems and high input commercial systems.

Demand for groundnut has been driven by several factors. In Africa, population growth has been the primary factor while in Asia increased demand for groundnut has been driven by a combination of

population growth, growth in per capita income, and urbanization. The demand for groundnut has also been influenced by relative prices of competing vegetable oil. Similarly the demand for groundnut meal is influenced by relative prices of other oilseed meal and cereal-based livestock meals.

Groundnut is extensively traded in domestic markets wherever it is produced. International trade in oil has fallen substantially over the past two decades while trade in confectionery groundnut products has increased. Concern over aflatoxin contamination has led buyers to impose strict tolerance limits for aflatoxin for both food products and livestock feed. Groundnut exports are concentrated in developing countries - with the exception of the USA in confectionery groundnut - while Europe dominates import markets for all groundnut products although it is gradually losing market shares to Asia.

International price of groundnut oil and meal has fluctuated widely over time. But over the long-term, meal prices have fallen gradually while oil prices have increased. A thin groundnut market dominated by a small number of exporters and high levels of substitutability among competing vegetable oil and meals have contributed to the wide fluctuation in international prices.

Governments in both developing and developed countries have intervened extensively in the groundnut sector through price and marketing policies that influence prices, costs, and/or producer incomes. In general government policies in developing countries have discriminated against the groundnut sector by directly suppressing producer prices although reforms implemented in recent years have partly reversed this trend. In contrast many developed country government policies have protected the groundnut sector through various price support and quantitative restrictions on imports that protected domestic production.

Notwithstanding success in a few countries, groundnut productivity has been stagnant in much of the developing world. Adoption of improved varieties and crop management technologies remains poor particularly in Africa. Future work must therefore focus on increasing adoption rates. Breeding strategies for the future will differ depending on the nature of the production system. Ensuring modest yields every season is a priority issue in low intensity systems while issues relating to crop quality is a priority in high input systems. Technologies are available, or likely to be available, to resolve many farm level production constraints in developing countries. But it is important to focus on the socio-economic, policy, institutional factors in order to increase adoption rates.

Groundnut production and consumption is expected to shift increasingly to developing countries in the medium term. Both area and yield are projected to grow considerably faster than they did in the 1970s and 1980s. Production is expected to grow in all regions but most rapidly in Asia. Per caput consumption will grow sharply in Asia, slowly in Africa, and decline in Latin America. Utilization will continue to shift from groundnut oil toward groundnut meal and especially confectionery products.

Conclusions

The world groundnut economy: facts, trends, and outlook is useful to scientists, policy makers, development practitioners and others interested in the crop. The combination of technical, economic, and policy information and the implications drawn for growth of groundnut production in regional and

global economies provides a valuable reference for anyone interested in groundnut production and how it can contribute to improving the welfare of smallholder farmers in the semi-arid tropics.

2.1.2 The World Chickpea and Pigeonpea Economies: Facts, Trends, and Outlook

By P. Parthasarathy Rao, P.K. Joshi, C. Johansen, J. Kumar, and H.A. Freeman

Background

The 'Facts and Trends' reports serve as important resource material for IARC and NARS scientists, extension personnel, and policy makers. These reports provide information on trends in production, trade and utilization and help establish the current outlook for ICRISAT mandate crops in different regions. The first two reports published were on sorghum/millet and groundnut. The third will be a combined report on chickpea and pigeonpea, the two ICRISAT mandate pulses. The objectives of the project are to:

- Review major production and utilization trends of ICRISAT mandate crops
- Highlight major issues affecting the production and utilization of these crops
- Summarize available data on national and regional production, trade and utilization

Methodology

- Compilation of secondary data at country / regional level for chickpea and pigeonpea
- Tabular and graphical presentation of data
- Econometric analysis of data for trends, growth rates variation, and significance levels.

Results

Drafting of the report is currently in progress. Results indicate that for both chickpea and pigeonpea there has been some diversification in production in West Asia for chickpea and in East Asia for pigeonpea, although South Asia still accounts for the bulk of production. During the last 20 years world chickpea production grew on an average by 2% per annum, mainly due to growth in area during the 1990s in South Asia. Pigeonpea production on the other hand grew on an average by only 1%. Production performance was more impressive in the 1980s due to large area expansion. Chickpea productivity grew steadily by around 1.5% per annum while pigeonpea yields have remained virtually stagnant.

Per capita availability of pulses (including chickpea and pigeonpea) has declined in the major producing regions. One consequence of this has been an increase in real chickpea and pigeonpea prices, in contrast to declining real prices for cereals and milk. As real prices rose consumers tended to shift to cheaper sources of protein. Although there has been considerable progress in developing improved chickpea and pigeonpea varieties, the yield increases have not been able to match yield breakthroughs in competing crops like wheat and oilseeds; and pests and diseases continue to be major yield reducers. Australia (for desi types) and Turkey (kabuli types) are the major chickpea exporters. Chickpea production in Australia grew by more than 20% per annum in the last 10 years, from a low initial base. The growth was spurred by demand for chickpea in South Asia and the Middle East. Trade in pigeonpea is relatively less, with no major exporting country, although in recent years Myanmar has emerged as an important exporter.

Conclusions

The report is not yet finalized. However, what is emerging is that there is a clear need to increase productivity of chickpea and pigeonpea to bridge the gap between supply and demand, and bring down real prices to the consumer. For the vast majority of the vegetarian population these crops are still the major source of protein.

2.2 Changes In Cropping Patterns in the Indian SAT

By T. G. Kelley, A. Gulati, P. Parthasarathy Rao, and Jayawant Mandar

Background

In the mid-1980s, India was importing about 30% of its requirement of edible oils, bringing the balance of payment under strain. A decision was then taken to achieve self-sufficiency in edible oils by 1990, with the launching of the Technology Mission on Oilseeds. India did achieve near self-sufficiency in edible oils by 1992-93, but its food grain production fell short of demand. A paradoxical situation came into being: importing wheat at much higher prices than was being paid to domestic cultivator, while at the same time producing edible oil at double the world prices.

At the same time India launched its economic liberalization program and was a signatory of the Uruguay Round Agreement (URA) of the General Agreement on Tariffs and Trade. Thus sooner or later Indian agriculture will have to face world market prices. This study addresses the issue of cropping pattern change in the semi-arid tropics of India in response to opening up of agricultural trade. In other words, the study will look at the domestic resource cost (DRC) of the current production of various agricultural commodities, and what are the likely gains or losses from moving towards globalization.

The main questions addressed in this study are:

- What have been the changes in cropping patterns since 1970 in SAT India and what factors underlie these changes, i.e., the role of price and non-price factors in inducing shifts in cropping pattern.
- Where does Indian agriculture stand in terms of efficiency in the use of domestic resources, if one considers the option of imports vis-à-vis home production.
- What efficiency gains/losses can be expected to accrue to India, if trade in agricultural commodities was opened up and input subsidies on water and fertilizer rationalized.

Methodology

Cropping pattern changes in the SAT were tracked over the past two-and-a-half decades from late 1960s to mid-1990s, aggregately for the whole of SAT, and disaggregately for specific regions or crop zones within the SAT. Both absolute and relative (relative to gross cropped area) area changes were analyzed.

Acreage and output response models were estimated to quantify the price and non-price factors influencing crop area changes.

For measuring resource use efficiency from the society's view point, domestic resource cost (DRC) or resource cost ratio (RCR) which measures the true cost of production of any crop was used.

The impact of a move towards free trade on major crops was analyzed using a multi-market model which takes into account the producers and consumers of the product, government budgets and foreign exchange earnings.

Three important results are:

- a) Dryland crops, including the coarse grains and some pulses have fared poorly compared to the oilseeds and the predominantly irrigated crops like wheat and paddy. Looking across all crops in the SAT, profit related factors best explain the observed crop area changes, though non-price factors are certainly not unimportant, especially irrigation.
- b) With the exception of soybeans, domestic oilseed production is found to be inefficient, whereas wheat and rice are not only efficient import substitutes but efficient export commodities as well. Coarse grains, cotton and pulses have lower economic costs than the major oilseeds, but somewhat higher than that for wheat and rice.
- c) Exports and imports would rise under liberalization, but more importantly, the net trade balance in agriculture would rise by over 40%. This would have a positive impact on rural incomes. The total value of the selected agricultural commodities would rise by about 13%.

Conclusions

This study enhances our understanding of the process of change in cropping patterns in the SAT India and clarifies issues related to globalization and its implications for resource use efficiency. Does India stand to gain or lose from changes in agricultural policies aimed at freer trade, fewer restrictions on domestic marketing and reduced subsidies on inputs? The analysis here suggests that trade liberalization in agriculture offers an opportunity to gain from trade by exporting commodities where India has a comparative advantage and by importing where it does not. Although comparative advantage is state and region-specific, generally speaking, India is internationally competitive for crops such as cereals and cotton, and less so for edible oils and pulses. Greater efficiency in resource use can be achieved through adjustments in trade and input price policy and by investing more research resources towards those crops having a comparative advantage in the SAT.

The project final report “Changes in Dryland Cropping Patterns and Resource Use Efficiency”, Grant No. 940-0804 by the Ford Foundation was completed. Publication of book entitled “Trade Liberalization and Indian Agriculture: Cropping Pattern Changes and Efficiency Gains with a Focus on the Semi-Arid Tropics”, Oxford University Press, New Delhi.

2.3 Development of the Indian District-Level Database

By T.G. Kelley, P. Parthasarathy Rao, and R.P. Singh

Background

Agricultural development planning is often complicated by extremely diverse agro-ecological and socio-economic conditions underlying agricultural practice currently observed. This study addresses the crucial question of how to create a useful number of spatial sub-divisions, i.e., a typology to aid development bodies whose geographic mandate spans the full range of diversity of Indian agriculture.

The objectives of the study are:

- Updating and expanding the Indian district level database.
- Development of a rainfed system agricultural typology, able to integrate both agro-ecological and socio-economic characteristics.
- Identify the nature and extent of distortions in trade and pricing policies pertaining to Indian agriculture and to determine how these have effected the efficiency status of different crops.

Methodology

An agricultural activity based typology is constructed using cluster analysis techniques. Agricultural activities include crop and livestock activities. Validity and stability analysis of the typology was carried out using discriminant analysis. Characterization of systems /zones with respect to crop and livestock performance.

To examine the impact of distorted policies on the efficiency status of different crops, four cropping systems were selected for in-depth analysis. Efficiency was assessed by estimating for major crops for each system domestic resource costs (DRC), and its derivative resource cost ratios (RCR), nominal protection coefficient (NPC), and private and social profitability.

Results and Discussion

The ICAR-World Bank funded project on Sustainable Rainfed Agriculture Research and Development (Module I) updated and expanded the district-level database for India. The database includes data on crop and livestock production, input use, land use, and key socioeconomic and agro-ecological variables for 383 districts. It builds on the earlier ICRISAT district level database with the addition of data for three eastern states (Bihar, Orissa and West Bengal) to the existing 10 states (Andhra Pradesh, Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Tamil Nadu, and Uttar Pradesh). Several new variables have also been added.

The database is divided into two sets: a fully apportioned data set covering the period 1966-94, i.e., district boundaries of newly formed districts are adjusted back to the 1966 base; and, an unapportioned data set covering the period 1990-94, with no adjustments made in district boundaries. Both the data sets have been validated and documented in two volumes. The documentation includes a list of the districts,

the methodology for apportioning districts back to 1966, the list and description of the data files, data clarification and anomalies, missing data, and data sources.

Using ARCVIEW software the database for all districts in the 13 states is now conveniently interfaced with GIS. Indeed, any combination of agricultural, climatic, and socio-economic data can be superimposed onto the district level map for analysis or illustrative purpose. Maps have been digitized based on two time periods, 1966 and 1991.

Conclusions

The value of this database is immense. To-date, no national research institute has ventured to maintain or update a data set of this magnitude. During the last several years, ICRISAT has provided earlier versions of the database to research scholars, national research institutes, and IARCs. The numbers of such requests were many, indicating a large demand for such data. Given the current and potential demand, serious consideration must be given to making the database as widely accessible as possible and to ensuring it continues to be maintained and periodically updated.

2.4 Rainfed Agriculture Typology for India Constructed and Characterized

By Jayawant Mandar, T. G. Kelley, P. Parthasarathy Rao

Background

A primary focus of the Sustainable Rainfed Agriculture Research and Development Module I project is the development of a rainfed agricultural system typology, able to integrate both agro-ecological and socio-economic characteristics. This integration is fundamental in establishing priorities for rainfed agricultural research and development.

Methodology

Previous approaches to the classification of agricultural areas have exhibited a preoccupation with potential without paying adequate attention to the existing scenario, and hence ignored key socio-economic factors limiting the ability of farmers to produce more efficiently and sustainably. The idea behind the new activity-based approach is that agricultural activities are an articulation of a farm's multiple objectives within the underlying agro-ecological and socioeconomic constraints of the environment. The need for and usefulness of a rainfed agriculture typology, the methods used in constructing the typology, the empirical results—including validation and stability analysis, and the characterization of the typology itself, are all addressed in this study.

Results and Discussion

The 16-zone agricultural activity based typology has been characterized in terms of geographic spread, dominant agricultural activities and temporal and spatial variability with respect to crop and livestock performance. Growth in crop yields, particularly for some dominant rainfed crops in central India, e.g., sorghum, millet, maize, and cotton, appear to have played a significant role in reaching high overall performance in specific zones over the past 20 years.

Conclusions

Information on the dominant agricultural activities must be an integral part of any attempt to classify districts in India—to help in designing agricultural research programs or in making infrastructure investments or in designing poverty alleviation programs for rural India. Although the activity-based typology is not a permanent system of classification, and may undergo moderate change over time, because it integrates both socioeconomic and agro-ecological factors, it is a highly appropriate research and development policy planning tool. Since it integrates both agro-ecological and socio-economic factors, there is no question of seeking a compromise between socio-economic and agro-ecological based typologies. This approach incorporates both. It is hoped that it will be given serious consideration for use in agricultural research and development planning in India.

2.5 Critical review of agricultural trade and input price policy in India

By A. Gulati, T. G. Kelley, P. Parthasarathy Rao

Background

One of the challenges facing policy makers in India today is devising strategies that promote the efficient use of resources in Indian agriculture. To promote resource use efficiency this study looks at the nature of Government interventions in trade and pricing policies of major crops and inputs in Indian agriculture.

Methodology

Documentation and critical examination of current policies.

Results

A review of trade and input pricing policies reveals that although Indian agriculture is free of any direct controls, numerous indirect controls exist in the domestic and external marketing of most crops. For example, imports and exports of major crops (pulses excepted) are highly regulated; domestic marketing is subjected to compulsory levies; and commodity movement restrictions, stocking limits and bans on futures trading for most commodities are still in place. There are large input subsidies on canal water, power, fertilizers and credit. Charges for canal water do not cover even 10% of operational and maintenance expenses, much less capital costs. Power is provided on a flat-rate basis, with some states like Punjab and Tamil Nadu providing power free of cost. Urea production remains under the Retention Price Scheme, which amounts to large subsidies on urea (1998/99 outlay estimated at Rs. 120 billion, or approximately US\$3 billion). Overall, the aggregate level of subsidy on irrigated crops is almost twice that of rainfed crops—but corresponds roughly to the same differentials in total value of production.

Conclusions

Restrictions in external trade, regulations governing domestic marketing and subsidies on key inputs result in considerable distortions in agricultural prices and this in turn has a major impact on cropping patterns and resource use efficiency in India. This indicates there is tremendous scope for enhancing resource use efficiency in the rainfed SAT by introducing reforms in trade, domestic marketing and input price policies.

2.6 Impact of Agricultural Policy Reforms in India

By T.G. Kelley, A. Gulati, and P. Parthasarathy Rao

Background

The impact of distortions in agricultural policies on the efficiency status of different crops was examined in four rainfed agriculture systems.

Results and Discussion

Two of the four systems—the rice based and the cotton/sorghum based—appear to be relatively efficient in terms of allocation of resources to crops with higher resource use efficiency. For the rainfed rice based system in eastern India, the Resource Cost Ratios (RCR) for the dominant rainy and post-rainy season crops, rice and wheat, are very low. Potato is another crop identified as being highly efficient in this system. In the cotton/sorghum based system, RCRs for cotton and sorghum are well below those of competing rainy season crops. Results indicate that by rationalizing input subsidies and liberalizing trade, both the rainfed rice based and the cotton-sorghum based systems could potentially reap substantial efficiency gains. Domestic marketing reforms to allow free movement of rice, abolishing stocking limits on private traders and introducing futures markets would help reduce marketing costs, making rice cultivation in the rice based system even more competitive internationally. To capture the efficiency gains in the cotton-sorghum based system, export quotas and minimum support prices must be removed.

The other two rainfed systems dominated by oilseeds, i.e., the soybean based system in central Madhya Pradesh and the groundnut based system in southern Andhra Pradesh, are not efficient in an open economy framework. Although RCRs for soybean and groundnuts in their respective systems are close to unity, they are relatively higher than for their competing crops. Thus, crops that dominate these two systems are comparatively less efficient in resource use. Liberalizing trade and rationalizing input subsidies in these systems may, at least in the short run, have an adverse effect on the income of producers. Nevertheless, introducing such reforms would facilitate a shift in cropping patterns to crops of higher comparative advantage, which is ultimately in India's long term interest. Irrigated crops are receiving almost twice the subsidy that their counterparts under rainfed conditions receive. Although the removal of subsidies would in absolute terms reduce profit margins of cultivators more on irrigated than rainfed tracts, the relative position of net profits would change only marginally in most cases. Thus, subsidy reforms, though desirable, may not dramatically change the existing cropping patterns.

Conclusions

Removing price distortions will induce farmers to allocate resources as productively as possible. But because of the differential impacts on producers, policy reforms will need to be carried out carefully considering the interests of those who currently rely heavily on crops that are less efficient. More research must be done at the regional (zonal) level to determine what crop and livestock activities are most competitive in a price-undistorted environment and to develop strategies to reduce hardships in making the transition to these enterprises by some growers in the aftermath of policy reforms.

2.7 Final Report on Sustainable Rainfed Agriculture Research and Development in India (Module I) Project Completed

T.G. Kelley, Mruthunjaya, A. Gulati, Jayawant Mandar, and P. Parthasarathy Rao

Background

Three major topics were covered under this special project: district database development; rainfed agriculture typology; and economic policy analysis.

Methodology

Presentation of critical findings and implications were made at two workshops, involving all project collaborators, World Bank, ICAR, NCAP, CRIDA, IFPRI, ICRISAT, and ODI.

Results

Final report of the Sustainable Rainfed Agriculture Research and Development project (Module I) was submitted to the ICAR-World Bank Project Steering Committee.

Publications (all submitted to ICAR-WB Sustainable Rainfed Project Steering Committee):

1. Database Development and Documentation (2 Volumes) [Topic 1, Module 1]
2. Rainfed Typology Construction and Characterization [Topic 2, Module 1]
3. Trade and Price Policies: Efficiency Impact on Rainfed Agriculture [Topic 3a, Module 1]
4. Supply Responsiveness in India's Rainfed Agriculture [Topic 3b, Module 1]
5. Database Development, Typology Construction and Economic Policy Analysis [Synthesis Report, Module 1]

Conclusions

This study contributes to achieving a better understanding of spatial and temporal diversity within the SAT India and of issues related to agricultural liberalization and implications for resource use efficiency. Ultimately, it has implications for the future competitiveness of specific crop activities in the face of freer world trade. This in turn helps ICRISAT in assessing future demand for new technology in specific zones of the SAT and in prioritizing and targeting its research on its mandate crops.

S3: Improved Investment Strategies in Natural Resources Management in the SAT

Team members

H.A. Freeman, D.D. Rohrbach, T.J. Wyatt, K. Palanisami, and Derek Thomas

Project goal

Improve the sustainable utilization of natural resources through better-targeted research for development.

Intermediate goal

Provide farmers with more effective, cost-efficient, adaptable natural resource management options, particularly through better exploitation of crop-livestock linkages and more efficient, sustainable water use in rainfed SAT cropping systems.

Project purpose

Natural resources are key assets of rural communities across the SAT. Socio-economic analysis can complement the biophysical assessment of these assets, resulting in more effective, relevant interventions. The focus will be on emerging water constraints in Asia, and the limited adoption of soil/water management technology adoption in Africa. The crop/livestock nexus will be a third point of concentration.

Outputs

Details are provided in the following pages, under six headings:

- 3.1 Characterization of soil fertility management practices in Kenya
- 3.2 Impact of fertilizer market reforms in semi-arid areas of Kenya
- 3.3 Factors influencing farmers' decisions to use alternative fertility management practices
- 3.4 Fertility management modeling in Zimbabwe
- 3.5 Alternative investment strategies for soil and water management in the Sahel.
- 3.6 Bioeconomic models to analyze resource use at multiple levels

3.1. Characterization of Soil Fertility Management Practices in Kenya *by H.A. Freeman*

Background

Recent participatory rapid appraisal study in semi-arid areas of Eastern Kenya indicated that farmers ranked declining soil fertility as the most important constraint to food production after moisture availability. Research and extension recommendations have been developed for application of inorganic fertilizer and animal manure to maintain soil fertility and increase crop productivity in semi-arid Kenya. Yet, many farmers consistently ignore these recommendations and apply levels of inorganic and organic nutrients levels much lower than the recommended rates.

Strategies to improve soil fertility management on smallholder farms require a better understanding of farmers' goals and priorities and the relative importance of factors that influence their decision to use alternative fertility management practices. This understanding provides a basis for developing and disseminating improved soil fertility management options that are more attractive and therefore have a high probability of achieving widespread impact on smallholder farms.

Methodology

Data for this study were collected in a cross-section household survey in the semi-humid, transitional, and semi-arid zones in Machakos district of Eastern Kenya from May to November 1997. The sample comprised 399 households selected at random from administrative records of the local district office. Data were collected by structured questionnaires and included information on farmer and household characteristics, crop production, livestock holding, ownership of farm implements and equipment, and soil fertility management practices. Descriptive statistics were used to interpret the data.

The objective of the study was to assess farmers' soil fertility management practices and constraints in semi-arid areas of Eastern Kenya. In addition the study identified key issues in soil fertility research and extension that would provide wider opportunities for improvements in fertility management practices on smallholder farms.

Results and Discussion

Table 1 shows that almost all farmers reported using some soil nutrient input to maintain on-farm soil fertility usually combining organic and inorganic sources of nutrient inputs.

Farmers realize the importance of inorganic fertilizer in maintaining soil fertility. Almost 40% of farmers in the survey used inorganic fertilizer as a component of their current fertility management practice. There was however significant variation in the rate of adoption of inorganic fertilizer across agro-ecological zones with higher adoption in the relatively higher rainfall zones. In the semi-arid zone only 13% of farmers reported using inorganic fertilizer. This proportion rises to 35% in the transition zone and in the wettest areas of the semi-humid zone over 80% of farmers were using inorganic fertilizer. Among farmers using fertilizer the average level of the nutrients applied for basal application was 97 kg of total nutrients and 63 kg. of CAN for top-dressing per farm. The median levels of nutrients applied shows that half of

the farmers using fertilizer apply 50 kg of nutrients or less per farm for basal application across all agro-ecological zones.

Table 1. Sources of nutrients

Nutrient source	Semi-humid zone	Transitional zone	Semi-arid zone	Total
Percent of farmers using				
Nothing	1	3	7	4
Inorganic fertilizer	81	35	13	38
Farmyard manure	88	87	86	87
Compost	46	35	13	32
Green manure	1	1	3	2
Legume intercropping	10	13	11	12
Legume rotation	10	8	12	9

The pattern of fertilizer use in the survey area suggested increasing adoption of the input over time although many farmers applied level of nutrients that were far below extension recommendations. Farmers cited several reasons for not using fertilizer with the reasons for non-use varying between farmers who had never used the input and those that tried and stopped. In general, the most frequent response for not using fertilizer relate to lack of money to purchase the input, its cost, and perceptions about risk and benefits from using the input. About half of the farmers using fertilizer in all agro-ecological zones reported that they did not have any major problems using the input.

Among those who reported problems with fertilizer the most frequent was lack of knowledge to use the input effectively. Less than one quarter of farmers in the survey cited availability as an important constraint to fertilizer use.

Farmyard manure, cited by 86% of farmers in the survey, was the most widely used soil fertility input. There was no significant difference in the proportion of farmers using manure across agro-ecological zones. Farmers' livestock herd was the most important source of manure in all agro-ecological zones. Hence, application of manure was closely associated with ownership of livestock. Only 15% of farmers in the survey reported buying manure from other farmers and less than 1% bought manure from the market. Declining availability of manure and high labor requirements were identified as the most important constraints on manure use in all agro-ecological zones. About 54% of farmers cited inadequate quantities of manure available and 40% cited high labor requirements as important constraint on manure use. Compost and green manure were less important sources of organic nutrients. Thirty-two percent of farmers in the survey used compost in their fertility management strategies. The largest proportion of these farmers, 46%, was in the semi-humid zone while 35% of farmers used the input in the transitional zone. Only 13% of farmers used compost in the drier zone 5. Relatively few farmers used green manure as an important nutrient source. Only 2% of farmers in the survey were using the input with the largest

proportion of these in the semi-arid zone. The size of household livestock holdings was strongly correlated with farmers' decisions to use animal manure or compost. Significant variation was observed in average stock units between manure and non-manure users as well as between compost and non-compost users. Although legumes were widespread in these areas few farmers cited legume intercropping or rotations as important methods for maintaining soil fertility.

Conclusions

The characterization of farmers' fertility management practices has improved our understanding of the range of fertility management practices farmers use, their limitations, and the opportunities for change. As a result of this study the CARMASAK project in KARI is fine tuning its research strategy to focus on those areas where the potential for achieving impact from its soil fertility research is high.

3.2. Impact of Fertilizer Market Reforms in Semi-Arid Areas of Kenya

by H.A. Freeman

Background

Prior to 1990, government intervention in the fertilizer import and domestic marketing was linked to delayed imports, inefficiencies in domestic distribution, inappropriate packaging, and rent seeking activities by government officials. These factors notably contributed to the observed low levels of fertilizer use in Kenya particularly in semi-arid areas since the parastatal Kenya Grain Growers Cooperative Union with its virtual monopoly over fertilizer distribution concentrated its activities in higher rainfall areas. Controls on fertilizer prices and statutory fixed marketing margins were also disincentives for private traders to distribute fertilizer in semi-arid areas. Continued poor performance in the agricultural sub-sector in the 1980s led the government to liberalize the fertilizer sub-sector through a series of policy changes that culminated in the elimination of import licenses and foreign exchange controls in 1993.

The underlying rationale for fertilizer market reform was to encourage wider adoption and higher levels of fertilizer use through the development of an efficient and effective marketing and distribution system led by a vibrant private sector. It was envisaged that a well-functioning private sector led distribution system would deliver the right type of fertilizer to farmers at the right time in appropriate packages and at competitive prices. Fertilizer market reform was therefore expected to increase market efficiency, which in turn, would reduce real fertilizer prices, generate sustained growth in crop productivity, and reduce rural poverty.

This study examines the investment behavior of private retail traders with a view to understanding the factors that influence their decision to sell inorganic fertilizer. The study also identifies areas where policy interventions can facilitate private sector investment in fertilizer trade and encourage wider adoption and farm level use of inorganic fertilizer in semi-arid areas.

Methodology

Data for the study were collected from a cross-section survey of private input traders in Machakos district of Eastern Kenya between September and November 1997. The survey was conducted in three major agro-ecological zones - the wet semi-humid zone with average annual rainfall of 800 to 1000 mm, the transitional zone with average annual rainfall of 600 to 800 mm, and the dry semi-arid zone with annual rainfall of 400 to 600 mm. Private input traders were randomly selected within each agro-ecological zone from sample frames of agricultural input traders collected by the district agricultural office. Data from a baseline survey on farmers' soil fertility management practices was used to stratify the sample into high, medium, and low potential for fertilizer adoption. The sample comprised 131 private input traders of which 44 were in the high potential zone, 39 in the medium potential zone, and 48 in the low potential zone.

Results and Discussion

The sample comprised 131 stockists distributed across the semi-humid, transitional, and semi-arid agro-ecological zones. Data from an earlier baseline survey was used to stratify stockists into high, medium, and low potential zones based on the level of adoption of inorganic fertilizer in their area. Sixty-two percent of stockists interviewed sold fertilizer with 44% of these in high potential areas, 31% in medium potential areas, and 25% in low potential areas. This distribution reflected, in part, the historical use of fertilizer in this area.

Fertilizer market reforms reduced entry barriers into fertilizer markets and raised the incentives for private sector investment in fertilizer trade. Table 1 shows that many traders in high, medium, and low potential areas started selling fertilizer after markets were fully liberalized in 1993.

Although there was growth in private sector participation across all adoption potential zones the response was remarkable in the medium and low potential areas that were not adequately served by the state controlled fertilizer distribution system before market reforms.

Many stockists were well informed of fertilizer prices and actively sought competitive wholesale prices. Few stockists stored fertilizer because the cost of storage was high and they could easily replenish their stock from wholesalers who were located in large commercial centers. Fertilizer trade was highly seasonal with fertilizer purchases and sales concentrated in a few months to coincide with planting decisions in the short and long rains. Nearly all stockists purchased fertilizer in lots of 50 kg bags and repacked them into a variety of smaller packages. Stockists reported that the 1kg and 2 kg bags were most popular with smallholder farmers because they were affordable and farmers perceived them to be adequate for the requirement of their relatively small farms.

Several stockists reported that profits in fertilizer trade compared favorably with other agro-chemicals because of the relatively large volumes traded and the high rate of turnover during the trading season. Table 2 shows that despite the increase in fertilizer prices the majority of stockists reported that the availability of different types of fertilizer, sales volume, and profit margins had increased since fertilizer markets were liberalized.

The growth of the private sector in fertilizer retail trade, smaller fertilizer packages, timely availability of fertilizer, and competitive fertilizer prices has been associated with a trend towards increased farmer access to fertilizer and rising farm level demand.

An econometric analysis of stockists' decision to sell fertilizer indicated that the probability of selling fertilizer increases with prior experience selling agro-chemicals, perceptions about access to fertilizer marketing information and relative profitability from selling the input. Stockists who faced liquidity problems, had no wholesale distributors and fertilizer trade information were less likely to be selling fertilizer. Stockists who were also located in areas with low potential for adoption of fertilizer were less likely to be selling the input. A surprising finding is that the decision to sell fertilizer is not influenced by the level of stockists' technical knowledge on fertilizer use. This finding has important implications for

proper advice on effective fertilizer use given that stockists are the most important source of fertilizer supply under liberalized markets. Analysis of marginal effects indicate that interventions targeted at improving fertilizer marketing information and relative profitability of fertilizer will have the greatest impact on decisions to sell fertilizer.

Table 1. Period stockist started selling fertilizer by agro-ecological zones (% distribution).

	Semi-humid (n=19)	Transitional (54)	Semi-arid (n=8)
Pre-independence period (<1962)	11	0	0
Post-independence (1963-89)	5	9	0
Reforming period (1990-93)	16	22	13
After decontrolling the sector fully	68	69	88
Total (n)	19	54	8

Table 2. Stockists' perception of changes since 1990 (% distribution)

	Increased	Decreased	No change	Don't know
Number of fertilizer suppliers	80	1	7	11
Supply of fertilizer	73	3	19	6
Types of fertilizers available	63	1	24	12
Transportation facilities	48	7	40	5
Volume of sales	77	10	9	5
Price	74	7	15	4
Profit margins	43	22	31	4

Conclusions

This study highlighted the key role stockists can play in the effective use of fertilizer. It provided convincing evidence for interventions by development organizations and NGOs working with research and extension systems to improve technical capacity of stockists to effectively disseminate fertilizer use information to farmers.

3.3. Factors Influencing Farmers' Decisions to Use Alternative Fertility Management Practices

By H.A. Freeman, Sieglinde Snapp, and D.D. Rohrbach

Background

Improving soil fertility management on smallholder farms is increasingly recognized as a major policy and research issue in addressing declining trends in per capita food production in Africa. Recent debates on soil fertility maintenance and replenishment strategies on the continent emphasize integrated nutrient management (INM) strategies involving combined use of inorganic and organic sources of nutrients as the way ahead. Application of inorganic fertilizer is a necessary component of INM strategies. Yet, current levels of inorganic nutrients applied on smallholder farms in semi-arid and higher rainfall areas are much lower than the optimum rates recommended by extension systems. This situation is complicated by a lack of empirical studies that articulate clear strategies for achieving greater use of inorganic fertilizer on smallholder farms.

The capacity to develop INM strategies in which inorganic fertilizer is a key component can be enhanced through a deeper understanding of the natural, social, and market environments in which farmers operate. In the context of soil fertility management strategies this requires a realistic analysis of farmers' goals and priorities and the relative importance of factors that influence their decision to apply inorganic fertilizer. It is therefore important to identify the determinants of fertilizer use on smallholder farms in order to assess the quantitative importance of various factors that influence use behavior and investment patterns. Armed with this information priorities can be set for the development and dissemination of INM technologies that is relevant and has high probability of achieving widespread impact on smallholder farms.

The objective of this study was to determine the factors that influence the adoption and intensity of fertilizer use on smallholder farm in semi-arid areas of Eastern Kenya. Recent research suggested that use of inorganic fertilizer is increasing in semi-arid areas of Eastern Kenya though it is being applied in relatively small quantities. The study therefore examines the types of research and extension strategies that are needed to encourage increased application of inorganic fertilizer on smallholder farms.

Methodology

Data for this study were collected in a cross-section random household survey of 399 households in the semi-humid, transitional, and semi-arid zones in Machakos district of Eastern Kenya. A Tobit model was used to analyze the determinants of farmers' adoption and intensity of inorganic fertilizer use decision. The analytical framework examines the fertilizer adoption process at the farm level. The dependent variable is the intensity of fertilizer use per farm measured as the total level of inorganic fertilizer applied on each farm during the first rain season of 1997 divided by the total cultivable area. The explanatory variables comprise those measuring farmers' characteristics, resource availability, production objectives, plot characteristics, technical knowledge about fertilizer use, perception of relative benefits, climatic

factors, and market orientation. Model results are used to predict both the probability of adoption of inorganic fertilizer and the intensity of use conditional on initial adoption for selected farm types.

Results and Discussion

The results indicate that experience using fertilizer, household food security status, location in the semi-humid zone, perception about the relative benefits of fertilizer, technical knowledge about fertilizer use, cash cropping activities, and land pressure have a positive impact on the decision to use inorganic fertilizer and intensity of use. On the other hand, family size and location in semi-arid zone have negative effects on the adoption as well as on the intensity of inorganic fertilizer use.

Of greater interest in this study is the articulation of clear strategies for increasing the use of inorganic fertilizer on smallholder farms. Predictions were made for the semi-humid and semi-arid zones (Table 1), considering five variables that have a positive and significant effect on application of inorganic fertilizer: experience, family size, food security status, technical knowledge, and cash cropping activities. Predicted probabilities of adoption and levels of inorganic fertilizer applied per hectare are computed for different farm types in the semi-humid and semi-arid agro-ecological zones. The predictions are made for a representative household with average family size, experience using inorganic fertilizer, and is food secure. The effects on probabilities of adoption and expected levels of application of inorganic fertilizer are determined for the different farm types by selecting appropriate values for the explanatory variables. The results from the model predictions provide some very useful insights. Of all farm types considered the probability of adopting inorganic fertilizer and use intensity is highest among farmers with technical knowledge about inorganic fertilizer use and have diversified into cash cropping activities under high land pressure in the wetter semi-humid zone. Predicted probabilities of adopting inorganic fertilizer and level of use intensities are much higher in the semi-humid than in the semi-arid areas. In particular, the probability of adopting inorganic fertilizer is very low in semi-arid areas especially among farmers who do not have technical knowledge on using the input and have not diversified into cash cropping activities.

For each farm type considered, the probability of adoption and intensity of inorganic fertilizer use increases with improvements in farmers' technical knowledge on inorganic fertilizer. Total inorganic nutrients applied increases between 18 and 36 kg per ha as technical knowledge improves in the semi-humid zone and between 3 and 13 kg per ha in the semi-arid zone.

Diversification into cash crops increases probability of adopting fertilizer even under conditions of low land pressure. Farmers who have diversified into cash crops apply higher level of inorganic nutrients per hectare compared to those who have not. The intensity of inorganic fertilizer use due to diversification into cash crops rises to as much as 40 kg per ha in the semi-humid zone.

Although probabilities of adoption are generally lower for farmers without technical knowledge the results indicate that farmers who have diversified into cash cropping activities are more likely to be using inorganic fertilizer regardless of the agro-ecological zone. Households facing high land pressure are more likely to adopt inorganic fertilizer and apply higher levels on nutrients per hectare. However, the effect of changes in land pressure on predicted probabilities of adoption and use intensity are much lower when

compared with the influence of technical knowledge and diversification into cash cropping. This suggests that though rising land pressure is necessary it is not sufficient to drive rising levels of fertilizer use on smallholder farms.

The study suggests the following implications for achieving greater impact from INM strategies:

- A shift in research paradigm from broad generalizations to a decision based approach based on a better understanding of the diversity of farmers' circumstances and heterogeneity of farming systems will enhance the relevance of research results and increase the probability of achieving impact from INM technologies.
- A shift in emphasis from strategies based on optimal levels of fertilizer application to those that focus on development and dissemination of better technical knowledge will improve fertilizer use efficiency and provide greater incentives for smallholder farmers to increase farm level application of inorganic fertilizer.
- Diversification into high valued crops or products with high value-added and good demand prospects, in terms of high income elasticity and reliable market, is a promising strategy for increasing intensification of inorganic fertilizer use on smallholder farms.
- There is need to broaden the conceptual framework for soil fertility management research from its strong production focus to a focus on food sub-systems that encompass production, post harvest, and market interventions.

Conclusions

The articulation of clear strategies for achieving greater use of inorganic fertilizer on smallholder farms is generating fresh interest among research and development workers on the potential of INM strategies. This interest has led to changes in on-farm experimentation within the CARMASAK project.

Table 1. Predicted probabilities of adoption and intensity of inorganic fertilizer use.

	With technical knowledge		Without technical knowledge		Change in fertilizer use ¹ (kg/ha)
	Probability of adoption	Fertilizer use (kg/ha)	Probability of adoption	Fertilizer use (kg/ha)	
Semi-humid zone					
High land pressure, Cash crop	0.90	77	0.70	41	36
High land pressure, no cash crop	0.66	37	0.36	15	22
Low land pressure, Cash crop	0.83	60	0.57	29	31
Low land pressure, no cash crop	0.53	26	0.25	8	18
Semi-arid zone					
High land pressure, Cash crop	0.67	22	0.37	9	13
High land pressure, no cash crop	0.34	8	0.12	2	11
Low land pressure, Cash crop	0.55	16	0.26	5	6
Low land pressure, no cash crop	0.23	4	0.07	1	3

¹ Calculates the difference in use intensity with and without technical knowledge on inorganic fertilizer.

3.4 Fertility Management Modeling in Zimbabwe

by D.D. Rohrbach

Background

The yields of the major grain crops in semi-arid farming systems of Zimbabwe are low despite research and extension efforts to develop and disseminate improved genetic materials. Even where improved cultivars have been adopted, yield gains are small. Moreover, substantial gaps exist between crop yields obtainable at research stations, on-farm trials, and farmers' fields. This gap can be primarily attributed to differences in management practices and inherent soil fertility.

Despite a long history of fertilizer experimentation, farmers refuse to accept recommended practices. Further efforts to develop more useable recommendations have been constrained by the high variation in rainfall, temperature, and soil conditions. This investigation aims to define more practical fertility management technology options by applying crop systems modeling, the economic analysis of investment priorities and participatory research. In combination, these techniques are expected to speed the analysis of a wider range of options suitable to farmer circumstances. The 1999 workplan targeted the completion of a baseline survey to identify the some of the main socioeconomic and farm system boundary conditions for practical technology options.

Methodology

A two part formal farm survey targeted a random selection of approximately 250 households (125 farmers in each of two target zones (Gwanda South and Tsholotsho) in Zimbabwe. These are target areas for the efforts of the SADC/ICRISAT Sorghum and Millet Improvement Program efforts to promote the adoption of improved management technologies.

The survey collected basic information on crop management practices relating to ploughing, time of planting, weed control, fertilization, and water management. These include estimates of the level of input use and timing of management practices. In addition, the survey collected basic data on farm wealth, education, investment priorities, income flows to evaluate at least four principal determinants of management practice.

The initial survey was implemented, as planned in March 1999. This delineated household resource levels and crop management practices through the first half of the cropping season. The second round, implemented in June 1999, collected harvest data and reviewed the determinants of management decisions in greater detail.

Results

Almost 50% of all small-scale farmers in the semi-arid regions of southern Zimbabwe have tried chemical fertilizer. However, recent surveys indicate that more than 95% of this experimentation has resulted from free fertilizer distribution associated with drought relief programs. Less than 5% of these farmers purchase any chemical fertilizer on their own. These surveys have also revealed that more than 50% of cattle owners do not use manure on their field crops.

Continuing concerns about low levels of fertilizer and manure use, and stagnant sorghum and pearl millet yields, have stimulated the development of a collaborative research program with Zimbabwe's Department of Research and Specialist Services to assess how to improve these trends. Three major

hypotheses have been proposed for low adoption rates for both the chemical and organic inputs. First, farmers may perceive fertilizer to be too risky. Second, small-scale farmers may recognize that fertilizer offers a positive return. However, the average level of this return may not be high enough to attract scarce capital away from alternative expenditures - for example school fees. Finally, farmers are hypothesized to have incorrectly judged the relative returns to investment in chemical fertilizer. Further survey work, on-farm trials and crop systems modeling are being implemented to test these hypotheses.

In September 1999, a workshop was organized to apply the simulation model APSIM to the analysis of 1997/98 season trial results. The workshop highlighted the importance of obtaining accurate soil parameters, crop coefficients and complete weather files for the modeling. Small changes in initial soil water or nitrate can have a large impact on sorghum and maize yields, even in drought prone semi-arid regions. Nonetheless, both the experimental trials and the models indicate substantial opportunities for improving productivity with as little as 10-15 kg of nitrogen added per hectare.

Conclusions

This research is on-going. In 1998, supplementary support was obtained from the Rockefeller Foundation and a Department for International Development grant was received for the period 1999-2001. The SADC/ICRISAT Sorghum and Millet Improvement Program also plans to apply the results of these investigations to the development of more practical recommendations for fertility management technology in Zimbabwe.

3.5 Alternative investment strategies for soil and water management in the Sahel By J.Ndjeunga

Background/rationale

Poor fertility of sandy sahelian soils remains one of the major constraints to cereal production in West Africa. All countries in the West African Semi-Arid Tropics use less than 10 kg.ha⁻¹ of nutrients compared to 200 kg.ha⁻¹ in western Europe. In Niger, for example, less than 1 kg.ha⁻¹ of plant nutrients per cultivated area is applied whereas nutrient mining is estimated to 16 kg.N.ha⁻¹, 2 kg.P.ha⁻¹; and 11 kg.K.ha⁻¹. There is therefore an urgent need to restore soil fertility and soil fertility restoration is and will remain a major issue pursued by development planners, policy makers and scientists. Previous research on soil fertility restoration options have been conducted on station under researcher management and have proven to significantly out-yield farmers' traditional method. However, few studies have been tested these soil amendment options on farmers' fields and under farmers' management to show that some options were economically profitable or could be preferred by risk-averse decision-makers. The main objective of this study is to determine the risk characteristics of phosphate fertilization strategies tested on farmers' field under farmers' management in two rainfall zones of Niger, within the framework of expected level of satisfaction (expected utility).

Methodology

On-farm trials were conducted at two sites (Banizoumbou (13°31'N,2°39'E) and Karabedji (13°15'N,2°32'E)) of Southwest Niger in 1996 and 1997. Both sites differ significantly by the soil chemical characteristics and amount of rainfall. Every year, on each site, an average number of 25 farmers were involved in the trials.

In 1996, a participatory rural appraisal survey was conducted in both sites in order to identify potential fertility options to be tested by farmers. After discussions with farmers, a list of 25 potential fertility options were identified. The first four soil restoration options were imposed by researchers and farmers were asked to choose among the remaining 21 options. Among options selected by farmers, two of these options were chosen by more than 75% of participating farmers and other options were scattered among other treatments and were not statistically representative. Many of the options rejected involved the use of crop residues and manure. Reasons for rejection were found in the limited availability of manure, and the competing uses of crop residues for house construction and animal feeding against soil amendment. Therefore, the following 6 treatments were tested and were entirely managed by farmers:

T1: farmers' control, no fertilizer is applied.

T2: Single super phosphate broadcast and incorporated at 13 kg P.ha⁻¹ (SSP).

T3: Tahoua phosphate rock broadcast and incorporated at 13 kg P.ha⁻¹ (PRT).

T4: Same as T3 plus 4 kg P.ha⁻¹ hill placed from SSP at planting time (SSP & PRT).

T5: the commercial NPK broadcast and incorporated (15-15-15) applied at 13 P.ha⁻¹.

T6: Same as T2 plus 30 kg N.ha⁻¹ as Calcium Ammonium Nitrate (CAN) broadcast and incorporated. N is split with the first split applied 3 weeks after planting and the second split 6 weeks after planting (SSP & CAN).

The estimation of cash returns followed standard budgeting principles. Stochastic dominance analysis was used to compare fertilizer treatments. The Kolmogorov-Smirnov test was used to test the difference between pairs of treatments tested. Because rainfall amount and its distribution could affect the effectiveness of soil amendments; the probability on the occurrence of rainfall per site and during the years 1996 and 1997 were computed using an Interactive Statistical Package (INSTAT) developed by the University of Reading in 1996.

Results

Stochastic dominance results show that pearl millet grain yields show positive fertilizer effects at all yield levels. Most of the cumulative distributions of yields for fertilizer treatments are generally to the right of the no-fertilizer control (T1) in both sites indicating that they provide higher yields under most conditions than the no-fertilizer control treatment. Compared to Banizoumbou, farmers in Karabedji have a better chance of realizing higher yields. This is explained by relatively high rainfall and better soil physical and chemical characteristics in Karabedji than Banizoumbou. In Karabedji, the control treatment (T1) has a 50% chance of achieving $450 \text{ kg}\cdot\text{ha}^{-1}$ or more; T4 has a 50% chance of producing $690 \text{ kg}\cdot\text{ha}^{-1}$ or more, and T5, $630 \text{ kg}\cdot\text{ha}^{-1}$ or more. Same as Banizoumbou, the commercial fertilizers significantly dominate the control treatment according to the K-S test.

In general, if government's objective is to attain country's cereal self-sufficiency²; estimated to about $400 \text{ kg}\cdot\text{ha}^{-1}$ at all costs, there is only about a 40% chance of attaining this yield level in Banizoumbou and a 55% in Karabedji using the farmers' traditional method. In Banizoumbou, the improved soil fertility restoration options have at least a 60% chance of achieving this level with the lowest achieved with the phosphate rock fertilizer, T3, and the highest with T6 (91%). Similarly, in Karabedji, the improved soil fertility restoration options have at least a 73% of chance of achieving this level with the lowest achieved with the phosphate rock fertilizer, T3, and the highest with the commercial NPK, T5, (94%). Overall, the improved soil fertility restoration options have the highest chance of achieving cereal self-sufficiency than the traditional method.

Since farmers have to purchase inputs and the cost of input used in the treatments differ, they would be interested in comparing relative net returns and their probability of occurrence. The distribution of cash returns from all 6 treatments were used for pair-wise comparisons of soil amendment alternatives, within the stochastic dominance framework.

Unlike grain yield comparisons, the effect of fertilizers on cash returns is less clear than the effect on yields. Stochastic dominance results show that farmers' traditional method (no fertilizer control) and a combination of natural phosphate rock broadcast at $13 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ and super single phosphate hill at $4 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ had the most desirable risk characteristics in both rainfall zones. In addition in the most favorable rainfall zone, the natural phosphate rock alone applied at $13 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ was also found in the stochastic efficient set. Choices among risk efficient soil fertility restoration options are contingent upon the availability of fertilizers, the reliability of fertilizer supply sources, the opportunity costs of capital and the resource endowments of farmers.

Simulation results show that at current input-output price ratio, most farmers-fertilizer users would choose the combination of TPR broadcast and SSP hill placed. If the availability of single super phosphate was limited, some farmers would use Tahoua phosphate rock alone. The demand for risk efficient alternatives could significantly increase if farmers could bear less than half the fertilizer costs at current output price.

Conclusions

This study contributes to the prioritization of a range of technology options likely to be competitive in SAT farming systems. It shows that there are soil fertility restoration methods that could be preferred by utility-maximizing risk-averse farmers and significantly improve yields and thus farm incomes. In

² This figure was computed using an average pearl millet yield of $340 \text{ kg}\cdot\text{ha}^{-1}$ in addition to 15% of this yield as cereal imports; i.e. $391 \text{ kg}\cdot\text{ha}^{-1}$ during the last ten years. This figure assumes that cereal deficits will only be filled by pearl millet. In effect, in Niger, pearl millet is the main staple accounting for about 77% of total per capita cereal consumption

addition, it highlights the need for agronomists to examine the interaction between water and soil nutrients across a range of production domains. In areas with low rainfall, there seem to be few soil fertility restoration choices available to farmers, whereas in areas with average to high rainfall, the set of soil fertility options is wider. The water conservation practices in drought prone areas will significantly increase the efficiency of fertilizer use.

Farmers' perceptions and preferences for alternative soil fertility restoration methods should be assessed. This may include an ex-ante assessment of the potential impact of such management changes. The studies should be linked with further analysis of policy, market and information constraints limiting investments in soil fertility restoration methods in the WASAT.

3.6. Bioeconomic Models to Analyze Resource Use at Multiple Levels

by T.J. Wyatt

Background

Bioeconomic models are a useful tool for integrating biophysical and socioeconomic data to examine how households determine the best use of their resources. Models are usually developed at a single level of scale and this project is developing models at the household, village, and district levels in West Africa. However, we are also trying to integrate the models at multiple levels in order to understand how decisions taken at the farm level can have repercussions at the village and district level (*e.g.*, the necessity of importing chemical fertilizer) and how policies at the district and village level can impact individual households (*e.g.*, closure of open access grazing land). Representative sites have been chosen in two agroecological zones in Burkina Faso, Mali, and Niger. The different countries permit a comparison of different policies and an examination of effect of market integration on the exploitation of household land, labor and financial resources. The goal of the project is to develop a methodology that can be used to construct multi-scale decision support systems that can be used by government agencies, including research, by development-oriented non-governmental organizations, by village authorities and by households to examine how decisions taken today will influence the availability of resources in the future. The bioeconomic models, which describe how households decide to allocate their resources, form the center of these systems.

Objectives

The ultimate objective is to provide decision-makers with a tool that will help them better understand the impacts of their decisions. The primary users will be government officials who must make policy decisions, research managers who must decide on allocation of resources toward the development of new technologies, aid project managers who must determine the best strategy for achieving their goals and village leaders and farmers who must allocate scarce resources in such a way as to provide for their families' immediate needs while preserving their resource base for the future. The specific objective of this milestone is to develop whole-farm, whole-village, and district models. These models integrate the various cropping, animal husbandry, and other off-farm activities that are characteristic of households in West Africa. The immediate objective is to better understand the constraints faced by household in realizing their goals.

Methodology

The models are mathematical representations of the physical and social environments using linear and non-linear programming methods. At the household and village level we use optimization techniques. This entails specifying an objective function (*e.g.*, maximize net revenue), detailing the constraints to achieving that objective (*e.g.*, production relationships and resource limitations), and defining other processes of interest (*e.g.*, soil nutrient balances and forage growth). At the district level, we incorporate general equilibrium conditions into the model to determine the impact of household's individual decisions on the aggregate market. This allows for feedback through the market for goods that are only traded within the district. The data for these models comes from multi-scale characterizations of the representative site, past research findings, and supplementary surveys and producer interviews. The project is a partnership with the national agricultural research systems (NARS) in the three countries. The NARS are responsible for data collection and provide valuable insights into the system to be modeled. The models are calibrated to the current observed situation and then 'experiments' can be performed. For example, a new millet variety with certain characteristics can be introduced into the possible crop choices. The model will select the new variety if it provides better returns to scarce resources without conflicting with other facets of the system. That is, if the new variety is higher yielding, but requires high labor input at a time when people are occupied with other critical tasks, the new variety may not be acceptable. In this way, researchers could examine alternate varieties or seek ways to reduce the labor requirement.

Results

For the case of Burkina Faso, models have been developed at the household, village and district level. The livestock sector is of major importance at the representative site. Export of live animals to the market in Côte d'Ivoire provides significant incomes. Tentative results suggest that milk products could provide a valuable secondary source of income as well, but that transporting and processing the product is a major constraint. A paper will be presented at third international symposium on Systems Approaches for Agricultural Development in Peru (November 1999) that utilizes the district level model to examine the impact of a village excluding transhumance herds from their territory. The model suggests that such a policy will have impacts on neighboring villages through changes in the price of milk and straw, products which are only sold on the district market and not for export.

Models have been developed for the household and village in the Malian case and efforts are now turning to the district level. The representative site in Mali is in an important millet producing region; livestock are of secondary importance. However, as in Burkina Faso, transportation costs have a significant impact on the farming system. In addition to the cost of imported chemical fertilizer, farmers implicitly pay up to

45% more in the cost of transport by donkey cart. There is a similar reduction in the implicit price received for millet sold. This makes chemical fertilizer relatively too expensive to use and farmers continue to rely on traditional practices of fallowing land and applying manure to selected fields. A paper presented at the American Association of Agricultural Economics meetings (August 1999) shows that subsidizing fertilizer prices will have little impact on fertilizer use because it does not effect the cost of transport. Moreover, a subsidy will not help the poorest households; the main impact will be on wealthier households that cultivate groundnut as a cash crop.

Progress in the Niger case has been slow, due to lack of resources within the Nigerien research system. However, household-level modeling is now proceeding with an emphasis on understanding the influence of climatic risk on farmers' practices. The representative zone in Niger is chronically food deficit, so another important aspect is market access and price risk. This is a more complicated situation and requires stochastic dynamic programming.

S4: More efficient seed systems

Team members

D.D. Rohrbach, J. Ndjeunga, A.B. Obilana, E.S. Monyo, R. Jones, P. Malusalila, R. Tripp, and R. Uaiene

Project goal

Promote the development of sustainable national and regional seed systems offering consistent access to the range of sorghum, pearl millet, groundnut, pigeonpea and chickpea varieties sought by farmers.

Project purpose

A main constraint to the adoption of improved varieties of crops of the SAT poor is the limited private-sector interest in commercial seed production. Seed companies commonly argue that sorghum, pearl millet, groundnut, pigeonpea and chickpea seed crops have limited sustainable market value and trade volume. Once farmers obtain a first set of seed, they will not return to the market to buy new stocks. As a result, seed distribution for ICRISAT's mandate crops tends to be carried out on an ad hoc and sporadic basis. In Africa, most of this distribution is through drought relief or resettlement programs. The objective of this Project is to work with seed companies, NGOs, and NARS partners to identify more sustainable mechanisms for seed supply of new varieties.

The project emphasizes case studies of alternative seed delivery mechanisms. This includes assessments of the relative efficiency of local village seed systems, NGO-led community seed system development schemes, and pilot commercial investments in seed marketing. All of this work takes place in Africa. Supplementary analyses are being encouraged on the efficiency of national and regional seed stocks (in southern Africa). The results of these analyses are being used in discussions with seed system policy makers and donors.

Outputs

Details are given in the following pages, under four headings:

- 4.1 Survey of local seed systems development options in Mozambique
- 4.2 Linking seed producers and consumers
- 4.3 Small seed packs sale - pilot program
- 4.4 Diagnostic analyses of the efficiency of national and village seed systems in Niger and Senegal
- 4.5 Comparative analysis of seed systems in Niger and Senegal

4.1 Survey of Local Seed Systems Development Options in Mozambique

By D.D. Rohrbach and D. Kiala

Background

Small-scale farmers in Mozambique have been heavily dependent on free seed distribution under drought and flood relief as well as post-war resettlement programs during most of the 1990s. Little is known about the impact of these programs, or the opportunities for developing more sustainable seed supply systems in the future. The most important traditional source of seed for most farmers in the country is the local or community seed system. Greater understanding of the structure and conduct of local seed systems can help identify strategies for strengthening these channels and exploiting them for the delivery of improved seed of alternative crops. There are likely to be opportunities for improving the quality of seed selection and storage by individual farm households. There may also be scope for commercializing the seed multiplication and distribution practices of farmers currently maintaining larger seed inventories. Improvements in the capacity of local seed systems to maintain community seed security stocks may reduce reliance on emergency distribution programs. This project examines the impact of seed deliveries under relief programs and the prospects for strengthening Mozambique's larger seed system.

Methodology

A formal survey of village seed systems in areas of the country where sorghum and pearl millet are relatively important and where World Vision maintains operations was completed in July 1998. This covered 360 households in 4 Provinces: Tete, Sofala, Zambezia and Nampula. Postcoding of these surveys was completed in November 1999. This year's workplan supported the completion of the initial data analysis and the drafting of a study report.

Finally, a one day seminar was organized to review strategies for the development of more sustainable seed delivery systems for sorghum and pearl millet and related crops. The seminar focused on the articulation of strategies for breeder seed supply, the role of the private sector, the role of the public sector and the contributions of non-governmental organizations.

Results and Discussion

From 1988 to 1998, the non-governmental organization, World Vision- Mozambique, distributed more than 10,000 t of seed to small-scale farmers in central Mozambique. Most of this seed was distributed under post-war resettlement programs targeting input delivery to farmers returning from neighboring countries. Additional seed was distributed to farmers affected by drought and floods. Almost all of this seed was imported from neighboring countries.

Mozambique faces a challenge to convert its dependence on emergency seed supply programs to a sustainable delivery system for improved seed varieties. Farmers need more consistent access to quality seed, and national crop improvement programs need an efficient delivery system for new varieties. These efforts are complicated by the limited development of market infrastructure in much of the country, and high marketing costs. Seed traders question the level of household demand, particularly for open or self-pollinated varieties. Some farmers have developed a dependence on emergency deliveries.

Despite the massive demand for seed for public distribution efforts, Mozambique's domestic production capabilities remain small. The national research service, INIA, has difficulty even maintaining breeder seed stocks of its released varieties. Commercial investment is limited to the production of small quantities of maize and rice seed for the most readily accessible markets. Most of the nation's commercial and public seed supplies are still imported. Much of the distribution effort remains *ad hoc*.

The foundation of Mozambique's seed system is the village market – the target of the research surveys and associated analyses planned under this project. These revealed that village seed systems are active

and reasonably efficient in meeting the annual seed requirements for most small-scale farmers residing in the survey regions. Farmers most commonly complain about the difficulty of maintaining high quality seed stocks from their harvest to the beginning of the next planting season. The survey respondents also complained about their inability to obtain new varieties of alternative crops. The analysis reveals that seed losses associated with war, drought and floods have probably been overestimated. However, there remains an undoubted need for well targeted emergency assistance.

There is substantial scope for improving the capacity of village seed systems to meet both annual needs for quality seed and periodic emergency seed requirements. Development investments also need to link local seed systems with the larger national seed market. Such linkages should prioritize the delivery of new, higher yielding varieties. Improved public sector investments are essential for the dissemination of the results of public crop breeding programs. Complementary private sector investments are needed to help farmers obtain access to higher quality seeds.

The research concluded by outlining options for the development of village seed systems. These options highlight links between the investment decisions of small-scale farmers, public sources of breeders seed, and private agencies involved in the multiplication and distribution of commercial seed. Priorities for the sustainable, development of the national seed system are highlighted. These were presented in a national workshop on seed systems development options.

The National Seed System Workshop, held on 16-17 June, brought together more than 40 participants from government, the private sector, non-governmental organizations, international agricultural research institutes, and donors to discuss opportunities for improving the flow of improved seed to farmers in Mozambique. The workshop was organized by the Instituto Nacional de Investigacao Agronomica (INIA), with assistance from ICRISAT, and opened by the Deputy Minister of Agriculture.

The workshop outlined national seed strategies, public and private sector seed supply activities, and problems constraining the further development of the seed system. Participants divided into three groups to discuss strategies for improving seed supply. Each group was asked to outline the components of an action plan for the development of the national seed sector. Topics for group discussion were divided as follows:

- Group 1 - Breeder and basic seed supply
- Group 2 - Commercial and emergency seed supply
- Group 3 - Community based seed production and distribution strategies

The results of the group discussions were reviewed and endorsed in a final plenary session of the workshop. These were formally presented to the Government of Mozambique in July 1999. In addition, a number of these ideas were integrated into an overall plan for seed systems development drafted by ICRISAT and INIA. Parts of this agenda have been proposed for funding under the national development plan for the agricultural sector (PROAGRI). Discussions continue regarding priorities for supplementary project funding.

Conclusions

This work provides an additional example of the structure and conduct of community seed systems. Related data have been collected in Zimbabwe, Zambia, and Malawi. We know these systems perform reasonably well at maintaining existing germplasm, but perform relatively poorly at distributing new germplasm.

As a result of ICRISAT initiatives, Mozambique established a national seeds committee to define priorities for government investment targeting seed systems development.

Outputs:

Rohrbach, David and Kiala, David. 1999. Development Options for Local Seed Systems in Mozambique. *[This paper is currently being finalized for publication as a SMIP working paper.]*

Rohrbach, David D. 1999. Seed System Development Options in Mozambique. Paper presented at the Mozambique National Seed System Workshop, 16-17 June 1999, Maputo.

4.2. Linking Seed Producers and Consumers

By D.D. Rohrbach and R. Tripp

Background

Most countries in Africa do not have reliable seed supply systems for food crops such as small grains and legumes. Parastatal seed enterprises have not met the challenge of ensuring seed supply for these crops. There is some commercial seed supply, but without hybrid technology the incentives for the private sector remain limited. NGOs and other local-level organizations have begun to experiment with a wide range of seed provision innovations, but these are limited in scope. The most effective strategy will involve some combination of public, commercial and local-level participation, but much work remains to identify the most effective and equitable strategies.

This project, primarily funded by DFID, aims to identify appropriate policies and strategies to expand and diversify national seed systems. The basic questions addressed by the project are:

- What can be done to ensure an adequate seed supply for grains and grain legumes?
- Is there sufficient demand for seed of these crops to expect a commercial seed response?
- *If so*, how do we stimulate the emergence of commercial seed activity?
- *If not*, what alternative seed provision strategies should be established?

Methodology

The project was initiated in late 1997 with initial discussions were held with policymakers, researchers, NGOs and other actors in the national seed systems of Kenya, Malawi, Zambia and Zimbabwe. In early 1998 stakeholder meetings were conducted in the four countries. Those meetings served to introduce the objectives of the project and to elicit a set of priority concerns for seed system development at the national level. They also helped to identify particular types of research that could be carried out in each country. The research was largely coinducted in late 1998 and early 1999. Finally, a set of wrap-up workshops were held to present the results of research at the national level and to discuss conclusions emerging from the research across the region.

Results and Discussion

The project studies in each of the four study countries led to the following recommendations and conclusions.

Public agricultural research. More investment is required to ensure that farmers have access to information about new crop varieties. Because there is often limited demand at the national level, crop breeding programs must place more emphasis on regional variety testing and release. Crop breeding programs must also ensure that breeder seed production is adequately funded and managed and that foundation seed production is done on a commercial basis. A position should be established within the research program that has responsibility for variety promotion and links with private (commercial and community-level) seed production.

Regulatory agencies. Variety registration should be simplified and mandatory performance testing should be abolished. Seed certification should be voluntary, but a system of truthful labeling should be vigorously enforced. Regulatory agencies need to devote much more attention to consumer education and point-of-sale monitoring.

Emergency seed programs. The costs of free seed distribution (in terms of dependence and the disincentive effect on seed enterprise development) should be assessed. When seed distribution takes place, more attention should be given to the provision of appropriate varieties and good quality seed. Seed distribution should be organized in a way to support local seed enterprise, not demoralize it.

Commercial seed sector. More attention should be given to the development of a network of well-trained input stockists. Seed companies should experiment with innovations for reaching small-scale farmers, such as experimenting with smaller pack size and better promotion. Support should also be provided for entrepreneurs who wish to link crop marketing to the development of seed provision.

NGO and donor seed projects. All seed projects should support the development of a transparent commercial source seed system. Any attempt at developing local-level seed entrepreneurs should carefully consider the costs of a sustainable operation before embarking on this type of activity. NGOs can do a great deal to promote variety diffusion by supporting farmers' capacities for variety testing and adaptive research, and by providing access to source seed that farmers can multiply and use. NGOs can also make a significant contribution by helping farmers make links to markets where they can sell their grain and by helping farmers become more knowledgeable consumers of purchased inputs.

Seed policy. Seed policy deserves the specific attention of policymakers at the highest level; a seed policy body should not be limited to representatives of the government bodies (research, extension, regulation, seed production) that benefit from current policies. Explicit attention needs to be given to the links between broader agricultural development policy and seed policy.

Donors. Donors need to do a great deal of work (and to re-examine their incentive systems) so that their seed projects are better co-ordinated and are more supportive of a coherent national seed policy. Both donors and national policymakers must realize that seed system development requires long-term strategies and commitments, not dozens of unconnected projects.

Conclusions

Twenty-three case studies of seed system performance and development options were completed in collaboration with partners in the public and private seed sectors of Kenya, Malawi, Zambia and Zimbabwe. Eight national workshops were held to review priorities for case study analysis and discuss the research findings. One synthesis report has been drafted and is currently being edited for publication.

The project stimulated a reconsideration of seed system development strategies in each of the four case study countries. The analyses have directly contributed to debates on regulatory reforms. The initial success of case study efforts promoting commercial investments in small pack seed sales in the rural market has encouraged the continuation of these activities in Kenya and Zimbabwe, and their expansion into Mozambique. Analyses of NGO operations have led to discussions on the further refinement of these models.

Participants in the four national summary workshops consistently endorsed the project conclusions. These workshops also stimulated a commitment to continue some of the analyses initiated under the project, and to work toward the implementation of some of the recommendations.

4.3. Small Seed Packs Sale - Pilot Program

By D.D. Rohrbach and P. Malusalila

Background

Seed companies in southern Africa have failed to invest in developing rural seed sales networks for crops other than hybrid maize. These companies commonly state their uncertainty about the level of demand for seed of open pollinated varieties. They also complain that rural retailers have no interest in stocking seed of subsistence crops such as sorghum or pearl millet. As a result, it is impossible to obtain pure seed of sorghum and pearl millet varieties, except in major urban areas. This severely limits the adoption of new varieties.

Almost all sorghum and pearl millet seed adopted by farmers in the four countries targeted under SMIP phase 4 (Botswana, Zimbabwe, Mozambique and Tanzania) has been derived from free seed distribution programs run by governments and NGOs. The common availability of free seed further limits commercial incentives to develop rural seed markets.

Yet, small-scale farmers commonly cite the lack of access to the seed of new varieties as their main justification for non-adoption.

Methodology

This pilot project tests the demand for seed of open pollinated varieties of sorghum and pearl millet (and groundnut and sunflower) in rural markets. It also tests the relative demand for seed sold in smaller package sizes. The results will be used to encourage broader private investment in the development of rural seed trade. This should directly contribute to speeding the adoption of new sorghum and pearl millet varieties.

A private company, the Seed Company of Zimbabwe, established 40 retail sales agents in the rural areas of Zimbabwe for the first time in 1998. Sixteen of these agents, based in drier regions of the country, were used for distributing specially developed smaller packages of sorghum, pearl millet, groundnut and sunflower seed. These included a cross-section of 5 kg, 2 kg, 1 kg and 500 g seed packages. All of the small packs seed were commercially sold at prices reflecting the true costs of packaging and distribution.

Two surveys were conducted to monitor the success of the scheme - one of the rural retailers and one of the farmers buying the seed. Seed retailers were asked to maintain a record book of seed buyers to facilitate the identification and interview of the farmers. The surveys were implemented shortly after the end of the seed sales season - in late January and early February 1999.

Both the Seed Co and SMIP monitored the sale of the seed from retail shops. SMIP took primary responsibility for the implementation of the two surveys and the analysis of the results of the scheme. A report summarizing the results of the scheme was drafted and two seminars were provided outlining the study results.

Results and Discussion

The small pack seed program ultimately offered approximately three tons of seed of the four crop varieties for sale. Almost two tons of seed was sold. Virtually all of the groundnut seed was sold, and farmers complained that stocks ran out quickly.

Quantity of seed distributed and sold through the small pack program, 1998/99.

Seed crop	Quantity of seed	
	Distributed (kg)	Sold (kg)
Sorghum	1374	1057
Pearl millet	85	23
Groundnut	635	620
Sunflower	987	177

Three-quarters of the sorghum seed was sold. The failure to sell the last 300 kg was because this was offered in areas where free seed was being distributed, or in areas where sorghum was not a major crop.

Only 27% of the pearl millet seed stock was sold because this was distributed long after the end of the pearl millet planting season. Most pearl millet is planted in October and November. Due to problems of seed testing and packaging, this seed stock was not available for sale until mid-December.

The study revealed that farmers are more willing to purchase open pollinated seed than past surveys (without seed sales) had led us to expect (Rohrbach et al, 1997). Similarly, rural retailers expressed interest in continuing to stock these seeds in the future. A commercially viable market appears to exist for small pack seed of open and self pollinated crops. The pilot program will be run for a second year to test these initial conclusions.

A secondary result comes in the form of a warning about survey responses to hypothetical questions. Farmers previously expressed a lack of interest in buying new seed when the opportunity for such purchases was not available. However, once the seed was locally stocked, purchases commonly took place. Similarly, rural shopkeepers were quick to change their views once the actual level of product demand was proven. While additional experience is required to test the sustainability of this market, the prospects for rural seed trade appear favorable. Commercial opportunities appear to exist for selling seed of a wide range of crops through much of southern Africa.

The assessment of the program to date has not closely examined the direct and indirect costs of its operation. This is proprietary information held closely by the executing company. The Seed Company of Zimbabwe will need to complete its own accounting of these costs. However, the limited public information available suggests positive returns to the expansion of seed markets in outlying semi-arid areas. If the commercial sustainability of this strategy can be proven, an important example will have been set for seed companies throughout Africa.

Output

Rohrbach, David D. and Malusalila, P., 1999. Developing Rural Retail Trade of Seed Through Small Packs. Paper presented at the Zimbabwe Seed Sector Stakeholders Meeting - 25 June 1999, Matopos.

[This paper is currently being finalized for publication as a SMIP working paper.]

Conclusions

The results of the first year pilot exercise were positive enough that the Seed Company of Zimbabwe has agreed to run this program a second year. The effort will be expanded across a wider range of traders, and will include at least one additional seed crop. This follow-up is essential for improving the accuracy of the estimation of seed demand. While traders are convinced that farmers are interested in buying small packs, no one knows how consistent this demand will be. Will farmers returned to purchase high quality seed every year? Or will they use the small pack program simply as a means to resolve periodic seed deficits? Can the program

offer an efficient means to introduce new varieties to small-scale farmers? Can rurally based retailers contribute toward the promotion of more rapid technological change?

4.4. Diagnostic Analyses of the Efficiency of National and Village Seed Systems in Niger and Senegal

By J. Ndjeunga

Background

During the last 20 years, governments and international donors have invested more than US\$45 million and US\$36 million in variety development, seed multiplication and seed distribution in Niger and Senegal, respectively. More than 17 new groundnut and 9 new pearl millet varieties have been released in Niger; though adoption rates for these varieties remain low. Similarly, 13 groundnut and 4 new pearl millet varieties were released in Senegal. Adoption rates for several of the new groundnut varieties are good, but lag for pearl millet.

The two countries are fairly representative of seed systems in other countries in the West African semi-arid tropics. The study compares the performance of the seed sectors of these countries and draws lessons regarding strategies to enhance seed supplies, trade and the adoption of improved varieties.

Methodology

Data were collected in Niger and Senegal in 1997/98 through institutional and farm household surveys on market and non-market seed transactions, seed selection, seed quality, seed storage, and seed security stocks. These were used to compare the performance of the seed sectors in these countries.

The institutional surveys encompassed data on formal institutions involved in seed multiplication and distribution, their linkages and operational procedures. These included research institutes, state seed production units, seed conditioning centers, seed laboratories, cooperatives, parastatal companies, NGOs, farmers groups, and extension services. Data on costs of seed production and seed prices were gathered from secondary sources.

At the rural household level, structured surveys were conducted in June-August 1997. Information was gathered on household seed sources and transactions, seed selection and storage methods, seed quality traits preferred by farmers, and village capacity to handle seed security needs for the years 1996 and 1997. A stratified random sampling procedure was used to select villages. Agro-ecological zones and accessibility were used as the stratification criteria. Within the strata, villages were randomly selected. Five rural households were randomly chosen in each village. Fifty-two villages and 302 households were selected in Niger, and 52 villages and 304 households were selected in Senegal.

The performance of the seed system was compared using two criteria: the national requirements for improved seed in each country and profit margins. Variables explaining seed sector performance include: the number of varieties developed and available to end users, the quantity of seed supplied, the quantity of seed distributed, the seed distribution network, seed selection and storage methods, seed security stock management and seed prices.

Results and Discussion

In Niger, despite the investment of more than US\$45 million in seed multiplication and distribution projects relating to pearl millet, public seed supply systems operate at a consistent loss while farmers complain about poor seed quality or lack of access to seed of improved varieties. In contrast, informal village seed systems work well. Farmers have more access to their traditional pearl millet varieties (30 out of 33 varieties planted by farmers were local varieties); and more than 99% of farmers consistently obtain pearl millet seed from their own harvests, from neighbors or from village markets. Seed quality is high with germination rate averaging 88%, average moisture content of 9%, few impurities and little fungi attack (8% on average). Village seed systems offer a cheaper and more efficient means of delivering seed to farmers.

In Senegal, ICRISAT's survey results show that the more than US\$ 36 million invested by donors and the government of Senegal in groundnut seed multiplication and distribution projects have been moderately successful. However, here too, the local village seed market works relatively well. Farmers draw their groundnut seed from various sources including their own stocks, local village markets or formal seed stores. Seed shortages are well resolved by cash and credit purchase through the local village markets or seed stores located within villages. There is a market for groundnut seed and all small-scale seed growers sell their entire seed stocks. A wide range of improved varieties are available and accessible to farmers. However, the lack of high quality breeder seed, and late delivery of credit to local village seed growers have limited the expansion of groundnut seed systems.

The government of Senegal has invested little in pearl millet seed multiplication and distribution and the private sector has shown little interest in producing pearl millet seed. Only 5 out of 40 small-scale seed growers produce improved pearl millet seed and small-scale seed growers complain of limited access to breeder seed of improved varieties, and a narrow profit derived from producing pearl millet seed. Farmers complain about lack of access to seed of improved varieties. In contrast, the local village seed market works relatively well. More than 95% of farmers draw their planting seed from previous harvests or village markets. Seed shortages are well resolved through cash seed purchase in village markets.

A comparative analysis of seed systems in Niger and Senegal shows that the informal seed systems in both countries still remain the main seed sourcing for many smallholder farmers. These systems perform fairly well at supplying seed to end-users, maintaining and disseminating varieties, distributing seed at relatively low costs, maintaining acceptable levels of seed viability, seed and seed health. These systems are also able to maintain and supply a large number of varieties at low transaction costs.

Formal seed systems perform differently at supplying and distributing seed to end-users in both countries. Primary indicators of performance show that on average, in Senegal, groundnut seed produced and sold covered on average between 1990-98, about 28% of the cropped groundnut area against 1% in Niger. However seed coverage for pearl millet are only marginally different in both countries (3.7% in Senegal against 1.2% in Niger). The differences in formal seed sector performance between the two countries were found in the level of development of their seed distribution network; the degree of integration of input-output markets; and private sector involvement in the seed industry. In effect, the poor seed distribution network, public sector inefficiencies and limited integration of input-output markets for both pearl millet and groundnut in Niger have limited the uptake of improved seed of both crops. In Senegal, the relatively well developed seed distribution network, and well-integrated input-output markets for groundnut have induced the uptake of improved seed of groundnut.

Publications. Two journal articles were submitted: "Local village Seed Systems and Pearl Millet Seed Quality in Niger" (submitted to Experimental Agriculture) and "Seed Systems in Senegal" (Submitted to Agricultural Systems).

Conclusions

Several lessons could be drawn from this study. These could be used to enhance the uptake of new varieties.

1. Crops of low commercial value such as pearl millet are more suitable for informal seed systems. To increase seed uptake focus on the improvement of the informal sector.
2. Input-output trade contracts could stimulate seed uptake of crops with low commercial value. For example, groundnut, which also has a low justification for seed purchase, has a higher seed coverage in Senegal than pearl millet. In contrast, in Niger, both pearl millet and groundnut have very low seed coverage.

3. Farmers' easy access to selling points could stimulate the uptake of improved varieties. The Senegalese system has a well-developed seed distribution network. All seed produced is sold, whereas in Niger, less than 30% of the (already limited) seed supplied by state seed production units is sold.

Future trends in seed sector development will likely be found in the establishment of sustainable institutions driven by the private sector. The development of institutions with clearly defined roles operating in a flexible legal environment are likely to increase the uptake of new varieties. The private sector will continue to be less interested in crops of low commercial value. This void should be filled by promoting local village seed systems whereby more efficient farmers or groups of farmers should be encouraged to multiply and disseminate improved varieties.

These studies have deepened our understanding of the structure, conduct and performance of pearl millet and groundnut seed systems in Niger and Senegal. These two countries are fairly representative of seed systems in other countries in West Africa. Two main lessons emerge from these studies that are useful for development planners, research and extension institutions in West Africa. For open-pollinated crops with low commercial value such as pearl millet and sorghum, there is little scope for private sector entry in the seed industry because of small profits. Because the local village supply systems work relatively well, a beneficial strategy for donors consists of directing a large share of funding towards improving the local village seed systems, particularly in maintaining and distributing seed security stocks in drought years. However, for crops with high commercial value where there is an organized market for the end-product, there is scope for private sector entry in the seed industry. For example, groundnut seed production is more commercially viable because groundnut is an export and cash crop.

The main roles for research and extension institutions should be to supply high quality breeder seed, and provide technical assistance in seed production to village seed growers. This situation could, however, change for the production of hybrid seed.

The studies highlight the fact that little is known about how farmers value a wide range of grain and plant traits and how much value they place on bio-diversity. There may also be scope for further policy analysis relating to the incentives influencing private investment in West African seed systems. Finally, this research suggests the need for development programs encouraging efficient seed producers in each community to become entrepreneurs tasked with the multiplication and distribution of new pearl millet varieties.

4.5. Comparative Analysis of Seed Systems in Niger and Senegal

Background

During the last 20 years, governments and international donors have invested more than US\$45 million and US\$36 million in variety development, seed multiplication and seed distribution in Niger and Senegal, respectively. More than 17 new groundnut and 9 new pearl millet varieties have been released in Niger; though adoption rates for these varieties remain low. Similarly, 13 groundnut and 4 new pearl millet varieties were released in Senegal. Adoption rates for several of the new groundnut varieties are good, but lag for pearl millet.

The two countries are fairly representative of seed systems in other countries in the West African semi-arid tropics. The study compares the performance of the seed sectors of these countries and draws lessons regarding strategies to enhance seed supplies, trade and the adoption of improved varieties.

Methodology

Data were collected in Niger and Senegal in 1997/98 through institutional and farm household surveys on market and non-market seed transactions, seed selection, seed quality, seed storage, and seed security stocks. These were used to compare the performance of the seed sectors in these countries.

The institutional surveys encompassed data on formal institutions involved in seed multiplication and distribution, their linkages and operational procedures. These included research institutes, state seed production units, seed conditioning centers, seed laboratories, cooperatives, parastatal companies, NGOs, farmers groups, and extension services. Data on costs of seed production and seed prices were gathered from secondary sources.

At the rural household level, structured surveys were conducted in June-August 1997. Information was gathered on household seed sources and transactions, seed selection and storage methods, seed quality traits preferred by farmers, and village capacity to handle seed security needs for the years 1996 and 1997. A stratified random sampling procedure was used to select villages. Agro-ecological zones and accessibility were used as the stratification criteria. Within the strata, villages were randomly selected. Five rural households were randomly chosen in each village. Fifty-two villages and 302 households were selected in Niger, and 52 villages and 304 households were selected in Senegal.

The performance of the seed system was compared using two criteria: the national requirements for improved seed in each country and profit margins. Variables explaining seed sector performance include: the number of varieties developed and available to end users, the quantity of seed supplied, the quantity of seed distributed, the seed distribution network, seed selection and storage methods, seed security stock management and seed prices.

S5: Competitiveness of ICRISAT mandate crops in the product market

Team members

J. Ndjeunga, A. Hall, H.A. Freeman, P. Parthasarathy Rao, and F. Agbola

Project goal

Assist developing countries to formulate policy changes to protect the livelihoods of the poor in the semi-arid tropics who depend on coarse grain and pulse production and marketing.

Intermediate goals

To gain a better understanding of the factors influencing shifts in cropping patterns and market competitiveness of coarse grains and pulses in the semi-arid tropics and the consequences of these shifts both for the livelihoods of the poor and research priority setting.

Project purpose

Traditionally, ICRISAT's mandate crops have been viewed primarily as food security or poor man's crops. Consequently, declines in area may suggest dietary changes for the poor; or conversely, expansion of area may be an indication of increasing poverty and food insecurity, although other interpretations are also possible. These studies will assess these issues, within the context of global trends towards freer trade. Particular issues for attention include: the potential for expansion in production of groundnut, pigeonpea and chickpea in Southern and Eastern Africa, in light of their low fertilizer requirement and high market value, export potential, and household food security consequences; and the potential for expansion of sorghum and millet in West Africa, through diversified utilization of these crops both for multiple food and feed products.

Outputs

Details are given on the following pages, under five headings:

5.1 Analysis of marketing constraints to pigeonpea in Kenya

- 5.3 Prospects for expanding commercial trade and use by food and feed industries in West Africa: the value of *tuwo* and *couscous* characteristics estimated
- 5.3 Diagnostic Survey of Sorghum and Pearl Millet Use by Industry in Botswana
- 5.4 Diagnostic Survey of Sorghum and Pearl Millet Use by Industry in Tanzania
- 5.5. Pilot Testing of Industry Supply Strategies for Sorghum and Pearl Millet
- 5.6. Preliminary Assessment of Market Prospects for Pulses in South Asia
- 5.7. Quantifying the value of grain quality traits in the Indian sub-continent pulse markets. Phase 1: chickpea market in India.
- 5.8 Diagnostic analysis on sorghum utilization prospects in India completed.

5.1. Analysis of Marketing Constraints to Pigeonpea in Kenya

By H.A. Freeman and R. Jones

Background

Scientists have long recognized that the performance of pigeonpea markets is an important component in the development and transfer of improved pigeonpea technologies in eastern and southern Africa. It is hypothesized that constraints on marketing limit the adoption of improved pigeonpea technologies resulting in reduced farm level productivity and household incomes. A sub-sector survey was conducted to test this hypothesis in Kenya.

The sub-sector analysis described the supply structure for pigeonpea, identified the participants, their functions, and the channels used to deliver various pigeonpea products to final consumers. A sub-sector map was used to link market intermediaries in a vertical system that channels inputs to producers and pigeonpea products to a network of traders, transporters, and processors before it reaches the final consumer.

The major objective of the study was to identify the principal pigeonpea marketing channels and establish links among intermediaries at each level in the marketing channel. Another objective was to assess the relative importance of farm level and post-farm level constraints and identify the opportunities for leveraged interventions.

Methodology

Data were collected from a combination of secondary and primary sources. A reconnaissance survey was conducted in June 1998 in nine major pigeonpea production and trading areas, to improve understanding of important pigeonpea markets, the categories of traders, and the pigeonpea varieties traded in these markets. Information was collected through a review of secondary data sources, informal interviews with key informants such as wholesalers and transporters, and direct observation of critical stages in the marketing channel. Based on the findings from the reconnaissance survey, a survey of pigeonpea traders was conducted in September 1998. A purposive sample was selected to include at least 2 respondents from each of the following categories, rural assemblers, transporters, rural wholesalers, urban wholesalers, urban retailers and rural retailers. Quantitative data were collected on prices, quantities traded, marketing costs, size of enterprises, functions and the technologies used. Market intermediaries were also requested to assess the constraints and opportunities for pigeonpea trading.

Results and Discussion

The survey identified eight different pigeonpea marketing channels. Of these five were identified for further investigation:

- Rural production – urban consumption of dry grain through the urban supermarkets
- Rural production – urban consumption of dry grain through the urban open-air markets
- Rural production – processing and export of dhal
- Rural production – export of dry pigeonpeas
- Rural production – export of vegetable pigeonpeas

Constraints to pigeonpea marketing were identified at each stage in the marketing channel. These included low volumes traded, storage – rudimentary storage facilities, low returns to storage, high risk of crop loss - lack of information on price, markets, quality and standards, residual markets resulting from limited marketing opportunities, lack of access to trading finance or credit; and poorly weak marketing infrastructure (rural transportation) resulting in high marketing costs.

Marketing margins were estimated for the major pigeonpea marketing channels to provide indicative performance of various participants in the marketing system. The study estimated gross marketing margins, because the nature of some of the marketing systems - including both cash costs and implicit costs – makes it difficult to estimate marketing costs precisely. Estimated marketing margins for selected marketing channels are shown in Table 1.

Table 1: Percent marketing margins for selected pigeonpea marketing channels in Kenya

Marketing chain participant	Channel 2	Channel 3	Channel 4	Channel 5
GMM _{RA} (rural assembler)	6.0	8.4	3.3	8.1
GMM _{RW} (rural wholesaler)	3.0	5.2	1.7	4.3
GMM _{UT} (urban transporter)	5.3	24.4	2.9	7.0
GMM _{UP} (urban processor/exporter)	31.4	-	60.3	41.9
GMM _{UR} (urban retailer)	25.7	20.0	15.9	-
TGMM (complete distribution chain)	71.4	58.0	84.1	61.2
GMM _P (producer share)	28.6	42.0	15.9	38.8

Channel 2: Urban retail of whole grain pigeonpea (Supermarket).

Channel 3: Urban retail of whole grain pigeonpea (Open market).

Channel 4: Urban retail of processed pigeonpea.

Channel 5: Export of whole grain pigeonpea

The analysis of marketing margin indicated that total gross marketing margin in the complete distribution chain is highest for urban retail of dhal followed by retail of dry pigeonpea in the supermarkets. In these channels farmers received the lowest share of the final consumer prices while urban processors and exporters receive the highest shares. Nonetheless without complete knowledge of marketing costs it is difficult to determine whether these margins reflect traders’ profits or point to inefficiencies in the marketing system.

Conclusions

As a result of this study ICRISAT in partnership with Technoserve, has identified opportunities for working with the private sector to test a range of alternative marketing arrangements that would reduce transaction costs in marketing and link pigeonpea producers into high valued markets.

5.2. Prospects for Expanding Commercial Trade and Use by Food and Feed Industries in West Africa: the Value of *Tuwo* and *Couscous* Characteristics Estimated

By J. Ndeunga and Carl Nelson

Background

This is a collaborative study by ICRISAT and INTSORMIL aimed at determining the potential for expansion of pearl millet in West Africa through diversified utilization both for multiple food products.

Methodology

Preference of consumers in Niger for different *tuwo* or *couscous* characteristics were evaluated using the conjoint analysis methodology. Data were collected for *tuwo* and *couscous* preferences through a structured survey in 4 sites. Preferences were estimated for three of the most consumer preferred pearl millet products (*couscous*, fermented *tuwo* and nonfermented *tuwo*) made from 5 pearl millet cultivars. The relative valuation for different traits by type of product is provided.

Results and Discussion

Preliminary results indicate that product taste, visual characteristics, and textural attributes are important. For example, in order of decreasing importance, taste or chewiness, color and cohesiveness are the most important attributes for pearl millet *couscous* consumers. For nonfermented *tuwo*, in order of decreasing importance, taste, color, consistency and cohesiveness are the most important. Consumers also expressed in order of decreasing importance their preferences for taste, chewiness, stickiness, consistency and mouthfeel for fermented *tuwo*. The different valuation of characteristics across products and ethnic groups, however, suggests that signals regarding preferences may be very noisy. Consequently, it might be difficult to design pearl millet improvement programs that are broadly acceptable. Increased demand for processed products requires investment by food processors in physico-chemical characterization of varieties to determine their suitability to specific processed products or develop products that would include traits that are preferred by consumers. Varieties that are not suitable for making consumer preferred products are likely to be rejected.

Conclusions

Commercialization of products made from pearl millet require food processors to place high value on some specific traits. For example, pearl millet *couscous* would require food processors to place high values on taste, chewiness, color and softness at touch. Failure to include those traits will constrain the demand for *couscous* products and the demand for varieties suitable for making *couscous*. Similarly the demand for cultivars for making fermented *tuwo* or nonfermented *tuwo* is likely to increase if *tuwo* prepared from these cultivars is tasty, light colored, consistent, with some amount of cohesiveness and good keeping quality.

This kind of analysis provides signals to breeders and food processors via food scientists as to what characteristics to look for when breeding for specific purposes or for processing commercializable products. Relationship between consumer ratings and laboratory measurement of pearl millet quality parameters should be emphasized. Physico-chemical characterization and their relationship with

consumer ratings of traits should be undertaken for all varieties to assess their suitability for processing consumer preferred products.

5.3. Diagnostic Survey of Sorghum and Pearl Millet Use by Industry in Botswana

by D.D. Rohrbach, K. Mupanda and T. Seleka

Background

The project aimed to evaluate the factors underlying the growth of the small-scale sorghum milling industry in Botswana, and quantify the levels of sorghum and pearl millet use by industry. Since more than 95% of the sorghum used by industry is imported from South Africa, the analysis examines opportunities for expanding the use of domestically produced grain. No pearl millet is industrially processed. Correspondingly, the study assesses industry interest in the use of this crop.

This research aims to provide a basis for discussions with the industry about strategies for increasing purchases of grain from domestic farmers. The diagnostic survey also aims to establish a baseline of current levels of utilization necessary for monitoring project impacts. The research aims to draw lessons for application in other SADC countries.

Methodology

Interviews with a cross-section of sorghum and pearl millet processors aimed to review levels of sorghum and pearl millet utilization during past 5 years, and sources of grain, concerns about variety type, grain quality standards sought and obtained; current factory gate grain intake prices, grain supply constraints, regulatory constraints, technology constraints, financial constraints, prospects for expanded demand. The survey also examined levels and determinants of margins between farmgate and factory gate prices; grain quality control; grain storage strategies; price levels and variability, capital or regulatory constraints.

Interviews with farmers were used to assess costs of production and competitiveness of domestic production with South African imports. Interviews with government representatives reviewed policy factors influencing recent and future levels of sorghum and pearl millet utilization.

Results and Discussion

During the past decade, Botswana has experienced rapid growth in the commercial processing of sorghum. In 1989, the country had 36 small-scale sorghum mills, most operating on a service basis - milling grain by the bucket or bag on behalf of individual consumers. By 1999, the number of small and medium scale sorghum mills had increased four-fold. The majority of these mills are now buying grain for processing and sale through local retail shops and supermarkets. The status of sorghum has changed from being a food security crop largely consumed in the rural areas, to become a commercial crop competing in the urban food market.

A study report (*Commercialization of Sorghum in Botswana: Trends and Prospects*) reviews the factors underlying the growth of the sorghum milling industry in Botswana, and the prospects for further market expansion. Four major factors underlie the growth. First, a preference for sorghum meal is widely held among domestic consumers. The recent growth of the sorghum milling industry has allowed sorghum to compete with maize meal as a commercial food product. The simple availability of sorghum meal on the retail market, at a price little different from maize meal, has led to a decline in the growth of maize consumption and possibly a decline in absolute maize consumption levels.

Second, a grain dehulling and milling technology was readily available, and strong efforts were made to encourage the use of this technology by a local parastatal. This technology provided a good quality meal product despite the variability in the quality of the sorghum grain input.

Third, the Government of Botswana provided the industry financial support encouraging investment in new

technology and expansion. The grants provided under the FAP sharply limited the risks faced by new entrepreneurs. The grants allowed millers to learn their craft and encouraged spillover effects on the manufacture of dehulling and milling equipment.

Finally, the growth of the sorghum milling industry depended on the consistent availability of an acceptable quality grain necessary to function throughout the year. While the government would have preferred that this grain come from farmers in Botswana, barriers to imports of sorghum grain were essentially eliminated. This caused the development of trading links between individual millers and a range of grain traders in South Africa, as well as the exploration of links with traders in Zimbabwe and Zambia.

The analysis highlights the limited impacts of the commercialization of sorghum processing on domestic sorghum production. Though sorghum is Botswana's main crop, most of the grain flowing through the domestic milling industry is imported from neighboring countries - principally from South Africa. This is mainly because the productivity of Botswana's sorghum production remains low. Yields average less than 250 kg per hectare. The returns to labor invested in sorghum production by the smallholder sector are generally lower than the rural wage rate. The growth of sorghum deliveries from the large-scale commercial farm sector depends on improvements in productivity in the sorghum enterprise. It is unlikely, however, that domestic sorghum production will ever contribute more than a small share of industry requirements.

Rohrbach, David D., Mupanda, Knowledge and Seleka, T. 1999. Commercialization of Sorghum in Botswana: Trends and Prospects. Draft.

[Draft submitted for review prior to being finalized for publication as a SMIP working paper.]

Rohrbach, David D. 1999. Commercialization of Sorghum Milling in Botswana: Lessons for Zimbabwe. Keynote presentation to the Workshop on Small-Scale Milling of Sorghum in Zimbabwe, 29, July 1999. ZESA Training Centre, Harare.

Conclusions

Many aspects of the Botswana case are unique, including the relative strength of consumer demand for sorghum meal, and the magnitude of government financial support for the development of the industry. However, the stimulus created by linking technology, finance and raw material supply is broadly replicable.

5.4. Diagnostic Survey of Sorghum and Pearl Millet Use by Industry in Tanzania

by D.D. Rohrbach and J.A.B. Kiriwaggulu

Background

The project summarizes the current and projected levels of utilization of sorghum and pearl millet by the national food and feed industry in Tanzania. In estimating future demand for sorghum and pearl millet, the project evaluates the relative significance of alternative constraints to expanded industrial utilization, including considerations of price competitiveness, grain and product quality, and processing technology.

These data establish the baseline for assessing the impacts of the interventions of SADC/ICRISAT Sorghum and Millet improvement Program and its partners on the quantities of sorghum and pearl millet used by industry, and more specifically, the quantities of grain supplied by small-scale farmers.

Methodology

All industry participants involved in trading or processing at least 10 t of sorghum and or pearl millet were targeted for interview. In practice, few entrepreneurs were using such quantities of grain. Correspondingly, the sample was broadened to potential processors of these crops. A formal survey questionnaire was used to review levels of sorghum and pearl millet utilization during past 5 years, and sources of grain, varieties sourced, grain quality standards sought and obtained; current factory gate grain intake prices, grain supply constraints, regulatory constraints, technology constraints, financial constraints, prospects for expanded demand.

A review of price data and associated survey information historically collected by the Marketing Development Bureau was used to assess levels and determinants of margins between farmgate and factory gate prices; grain quality control; grain storage strategies; price levels and variability, capital or regulatory constraints. This extended to the assessment of policies affecting the competitive position of sorghum and pearl millet for domestic industry.

Results and Discussion

Tanzania annually produces over 500,000 t of sorghum and 200,000 t of pearl millet. These are the second and fourth most widely grown cereal grain crops in the agricultural economy. Yet virtually the entire production is carried out on a subsistence basis. Less than 2% of each season's harvest enters the formal market. Virtually all of this is consumed by small-scale brewers of traditional beer. The remainder is consumed on the farm.

The lack of a commercial market has limited the interest of farmers in improving the management of these crops. As a result, average sorghum and pearl millet yields remain little changed over the past 15 years. However, the area planted to these crops is still increasing. The continuing growth in the number of farmers in Tanzania's drought prone, semi-arid areas contributes to a one percent average annual gain in sown area. Sorghum and pearl millet remain essential for household food security.

On the basis of a utilization survey, a review of price data, and associated discussions with industry representatives, it appears that the easiest opportunity for expanding the use of sorghum is in the opaque brewing industry. A target of 75% substitution over the next five years would create a demand for 1,800 t per year of high quality, white sorghum. This demand could possibly double once Darbrew's new breweries planned for Mwanza and Mbeya are commissioned. The main constraint limiting the expanded use of sorghum in opaque beer is the lack of adequate quantities of clean grain.

The main constraint limiting the use of sorghum and pearl millet by Tanzania's animal feed industry is the relative grain price. Yet a review of historical price data for Dar-es-Salaam's

wholesale markets indicates that sorghum has been competitively priced, relative to maize, in most years. Animal feed manufacturers should be able to guarantee themselves a white sorghum supply at prices averaging 15% below the price of maize, particularly if this grain is purchased immediately following the harvest. If stockfeed manufacturers purchase grain only as this is needed during the year, there is justification for using sorghum during the post-harvest period when prices are lowest relative to the price of maize. The industry can switch then use of maize as sorghum prices rise relative to maize prices during the pre-harvest season.

If grain is available at competitive prices, five years from now, sorghum could account for at least 5% of the grain used by the national stockfeed industry. If sorghum supplies become more consistent, and prices remain competitive, this could readily increase to 20% of grain throughput. The absolute level of demand at a 5% substitution rate for maize grain is roughly estimated at 5,000 t per year.

The potential size of the market for milled sorghum and pearl millet meal is most difficult to estimate. This is largely because of uncertainty about the strength of consumer preferences for alternative grains. The current market for sorghum meal in Tanzania is extremely small. There is almost no market promotion. Sorghum meal sells at a large price premium relative to the cost of maize meal. It is impossible to determine how much meal could be sold with a more competitive price, and an investment in product promotion.

Most immediately, the size of the market for sorghum and pearl millet meal in Tanzania needs to be more methodically tested. This includes the use of advertizing and product promotion to encourage consumers to try the new meal product. Investments are required in testing the demand for alternative types of meal (including alternative extraction rates) and various sorts of packaging (e.g. clear or paper). The price sensitivity of consumer demand needs to be evaluated. How will sorghum meal sales be affected if this product is placed on the market at a price similar to the price of maize meal? What if the price of sorghum meal is set 5% below the price of maize meal? The analysis of the market needs to include the consideration of opportunities for segmentation. Sorghum (or pearl millet) meal sales may first be targeted to parts of the community with residents originating from sorghum (or pearl millet) growing regions.

The milling industry should set a target of replacing, perhaps, 5% of the maize meal sold in Dar-es-Salaam with sorghum meal. In addition, the baking industry may profitably aim to replace 5% of the wheat used for bread and biscuits with sorghum flour. The combined usage could generate a demand for over 20,000 t of grain per year.

The prospects for pearl millet are less favorable than for sorghum given the generally higher price for this grain, and lower average yields and labor productivity. However, there may be a small market niche for pearl millet based meals, particularly in communities drawn from pearl millet production zones. The milling industry could test this market with an initial throughput of 500 to 1000 t of pearl millet grain per year.

Rohrbach, David D. and Kiriwaggulu, J.A.B., 1999. Commercialization Prospects for Sorghum and Pearl Millet in Tanzania. Paper presented at the National Seminar on Sorghum and Millet Commercialization, 19 September, 1999, Dar es Salaam.

[This paper is currently being finalized for publication as a SMIP working paper.]

National Seminar on Sorghum and Millet Commercialization, 19 September, 1999, Dar es Salaam. Co-sponsored by ICRISAT and Marketing Development Bureau, Ministry of Agriculture and Cooperatives.

Conclusions

These results provide evidence of the difficulty of commercializing sorghum and pearl millet in the SADC region. As in most SADC countries, there is virtually no commercial use of these grains due to industry skepticism, lack of experience and unfavorable price and supply parameters. Yet, at least in Tanzania, historical price data suggests commercial production may be possible with the development of stronger market linkages. If this is true, a hypothesis to be tested over the next workplan year, the evidence of success should provide an example for other SADC countries.

5.5. Pilot Testing of Industry Supply Strategies for Sorghum and Pearl Millet

By D.D. Rohrbach, C. maovera, N. Mhazo, A.B. Obilana

Background

Industry purchases of sorghum and pearl millet grain are limited by uncertainty about the availability of grain to the industrial market, the quality of this grain, and price levels. This uncertainty largely reflects the historical lack of development of this grain market. National markets for maize have been largely developed through parastatal interventions and the dominant demand of the maize milling industry. As a result, farmers commonly acknowledge the existence of a national market for maize. However, few perceive any significant demand for sorghum or pearl millet. The perception of maize as a cash crop encourages the allocation of land to this commodity, even in highly drought prone regions. Farmers are discouraged from producing more sorghum or pearl millet because of the view that no demand exists for surplus production. While a few companies buy small quantities of sorghum or pearl millet in the rural market, this demand is perceived to be uncertain and limited. If purchases of sorghum or pearl millet become more consistent or reliable, production is likely to increase.

The uncertainty undermining the development of the grain market is reinforced by the variability of grain production levels in the drought prone environments where sorghum and pearl millet are commonly grown. Traders are unsure where to find grain and the level of grain available on the market is highly variable. After favorable rains, grain supply may be in excess of industry demand. However, in drought years, grain may be difficult and costly to find. This reduces the interest of industry in developing food products dependent on sorghum or pearl millet grain.

If sorghum and pearl millet are to become competitive inputs to industry, marketing costs need to remain low and grain supplies must be more assured. These objectives may be pursued through grain formal or informal contracting. Farmers need to be informed of industry interest in buying sorghum or pearl millet grain, of particular quality standards, at the time of planting. Farmers and industry may agree on a target price - though this may be subject to renegotiation at the point of harvest. Most importantly, farmers and industrial buyers need to develop an understanding of each other's intentions and an on-going relationship based on trust. This process likely takes several years of interaction.

Methodology

The SADC/ICRISAT Sorghum and Millet Improvement Program is encouraging the private milling company Induna Foods and the private brewing company Ingwebu Breweries to expand their purchases of sorghum and pearl millet from small-scale farmers in Zimbabwe. This pilot project monitors efforts to initiate grain supply from several smallholder farming communities to industry and diagnose constraints to the development of commercial grain trading channels directly between farmers and industry. This pilot project is being initiated on a small experimental scale during the 1998/99 cropping season. It is expected, however, that the project will be revised and continued for two additional years.

The demand of Induna Foods for sorghum and pearl millet and the demand of Ingwebu for pearl millet was advertized in 3 different communities in southern Zimbabwe: Tsholotsho, Gwanda South, and Zvishavane. This included the delivery of sorghum and pearl millet seed of varieties suited to production for industry in each of these communities. The farmers in each community were told of the minimum price and grain quality standards each industry was willing to use in purchasing grain. Farmers were then encouraged to produce directly for these industries - either on a formal (signed) or informal (verbal) contract.

The production was monitored during the course of the season, most closely around the time of grain harvest. This is essential to ensure farmers are well aware of industry quality standards and to estimate intake at the end of the season. The costs of monitoring were divided between industry and SMIP. The ultimate quantity of grain supplied to industry is being recorded.

Results and Discussion

Two different contracting methods were ultimately employed to encourage farmers to grow sorghum for Induna Foods. In Zvishavane District, approximately 300 farmers signed written contracts to provide 300 t of white sorghum. Each farmer received seed for free, though the value of this seed was to be subtracted from the ultimate grain payment. The farmers were promised threshing services to be organized by the Development Technology Centre of the University of Zimbabwe.

In two other areas, Gwanda South and Tsholotsho, farmers in areas where SMIP was promoting improved crop management were encouraged to grow sorghum for Induna Foods without written contracts. Also, no seed was provided except in the context of a limited collaborative trials program. Again, however, mechanical threshing services were promised. Approximately 50 t of sorghum was sought from Gwanda and 150 t of sorghum was sought from Tsholotsho.

None of these 'contracts' proved particularly successful. Farmers in Tsholotsho only delivered about 30 t of sorghum grain. We have yet to diagnose the reasons for the failure of these written contracts. However, one problem is that the threshing machines supplied by the Development Technology Centre commonly broke down. In addition, some of the sorghum grain may have been sold to other traders.

In Gwanda, only about 5 t of sorghum was received, in part because of the low yields achieved in this drought prone region. In Tsholotsho, only 40 t of sorghum was obtained. The main constraint here also was low productivity and competition from other buyers.

Induna has decided to facilitate more commercial production by distributing 8 t of sorghum seed at the beginning of the 1999/2000 season. This distribution is already underway. It is expected that as farmers become more accustomed to producing for the market, productivity and production levels will improve.

Conclusions

The project has also revealed that the mechanical threshing machines are not economical. These are simply too difficult to move from farm to farm as grain is sought. The available machines are also prone to breakdowns. The season's experience has encouraged the search for grain cleaning equipment suitable for the millgate.

The project has also revealed the need to monitor prices and the buying activities of competitors closely as the buying season begins. Farmers are less inclined to honor a written contract than to sell their grain to the buyer offering the most immediate cash. There may be scope, in a continuation of this pilot exercise, to strengthen links with several grain buyers. These traders could take primary responsibility for grain assembly, rather than relying on the miller to work with hundreds of farmers.

Finally, the project has exposed the need to identify traders capable of holding grain inventories throughout the year. This requires more capital than is available to most small-scale millers. It also requires access to storage space with reliable pest control.

The pilot project will be continued during 1999/2000 marketing season. SMIP expects that a similar project will be pursued in Tanzania in conjunction with the brewing industry. This will provide a basis for comparative analysis. It is too early to draw implications for other SADC countries.

5.6. Preliminary assessment of market prospects for pulses in South Asia

By T.G. Kelley, F. Agbola, P.P. Rao

Background

Australia's performance with respect to pulse production and exports since 1980 has been extraordinary. Having emerged from virtual obscurity, Australia is now a major player in the global pulse economy. However, the future of Australian pulse industry, particularly chickpea depends to a large extent on sustained growth in the demand for pulse imports from the Indian sub-continent (ISC). This study seeks to provide an understanding of the factors influencing the supply and demand for pulses in the region.

The objectives of the study are:

Understand supply constraints in ISC for pulses

Model supply and demand fundamentals in the ISC pulse economy

Critical review of previous developments in the ISC pulse economy – trends in domestic pulse production, imports, consumption and prices – and factors influencing those trends.

Assess developments in the Australian pulse industry with particular attention given to pulse quality issues.

Results and Discussion

There is a market for pulses in the Indian Sub-Continent (ISC)—the largest pulse consuming region in the world—for which Australian-produced pulses, mainly chickpea, field peas, and lentils, compete with domestic ISC producers and other suppliers such as Turkey and Myanmar. Population and income growth in the ISC are exerting a positive influence on the size of this market, but urbanization, changes in tastes and preferences and relative prices (vis-a-vis competing foods like meat and milk products) are having the opposite effect. There is no question that per capita consumption of pulses in India, Pakistan and Bangladesh is falling and it appears that aggregate demand is growing only very slowly and may soon level off or even decline. While the total demand may remain relatively static, the demand for higher quality or niche market pulses will rise. The demand for low quality pulses will probably fall the fastest. The demand for higher quality pulses may be met by exporters such as Australia, Myanmar and Turkey if their pulses match specific market requirements and prices are competitive (vis-a-vis Indian producers).

A number of key economic, political, social and technological factors are likely to influence the prospects for expansion of pulse imports to the ISC over the next 5 to 10 years. These range from, among others, domestic agricultural policy reform in India and other major pulse producing countries to global trade reform in compliance with the WTO, and from macro-economic policies influencing exchange rate movements to regional shifts in pulse grower competitiveness as a result of adoption of new crop technologies--generating yield, cost and quality advantages. Given the uncertainty surrounding many of these developments and their likely large impacts, it is difficult to be overly optimistic about the long-term prospects for pulse exports from Australia to the ISC, particularly for the relatively undifferentiated bulk commodity market. Production incentives in India could markedly shift in favor of or against pulses due to a changing economic environment brought on by forces from within and without.

Looking at ISC consumer demand, there is sufficient evidence to indicate that while pulse traders and consumers in the ISC are price conscious, they are not only price conscious. Indeed, they are discriminating between, and offering price premiums for specific pulse products based on quality differences. The wholesale and retail markets for pulses in the ISC are reasonably segmented and diverse, with preferences based in many cases on traits characteristic of traditional local land races which often vary from location to location.

Final Report entitled 'The Fundamentals of the Indian Sub-Continent Pulse economy: Long term Implications for the Australian Pulse Industry' submitted to GRDC. 1999.

Prospects for Expansion of Pulse Exports from Australia: Looking Back to Look Ahead. Background paper for pulse market research project, 1998 (limited distribution).

Conclusions

Pulse exporters like Australia must begin to discriminate within the bulk commodity market in the ISC for each of the pulses. A systematic pulse market study in the ISC would provide essential information about the relative importance of specific quality attributes (e.g., seed colour, size, and shape, taste, cooking time, dehulling and splitting recovery, etc.) in chickpea, dry pea, lentil and other pulses for specific niche markets. The key lies in adopting a "market needs" approach and, ultimately, in offering a more diverse range of grain types to establish niche outlets, a range that reflects and targets local market preferences. If the export pulse industry can address this fundamental requirement, it will go a long way in strengthening their competitive position in the ISC pulse markets.

More attention must be given to pulse quality improvement in the breeding programs, that is, explicitly targeting preferred non-yield traits associated with better grain quality when the price differential warrants such effort. These targets should reflect critical market information derived from ISC pulse market studies that indicate where the greatest marginal value accrues from specific quality enhancement.

5.7. Quantifying the value of grain quality traits in the Indian sub-continent pulse markets. Phase 1: chickpea market in India.

By. F.Agbola, P.Parthasarathy Rao, T.G. Kelley

Background

There is a market for pulses in the Indian sub-continent (ISC), for which Australian producers must compete with domestic ISC producers and other suppliers.

Pulse traders and consumers in the ISC discriminate between and price premiums for specific pulse products on quality differences, with preferences based in many cases on traits characteristic of traditional local land races, which often vary from location to location. This project is a first attempt to quantify the value of superior grain quality traits based on market analysis of selected pulse crops in the ISC of interest to Australia. This particular proposal focuses on chickpea.

Objectives

Provide strategic information to the Australian pulse industry on preferred grain quality traits in chickpea and price premiums associated with them. Specifically:

Characterize consumer preference for chickpea grain quality in India through market surveys and sampling techniques.

Assess the influence of quality – in terms of seed attributes and purity standards – on prices of imported chickpea.

Methodology

Market survey: Interview key players involved in the chickpea trade (wholesalers, importers, processors, and retailers).

Collect chickpea variety samples from 8-10 primary and secondary markets in major chickpea growing states in India.

Lab analysis of samples for selected quality characteristics.

Statistical analysis using multi-variate regression analysis.

Results

The Indian chickpea market is segmented mainly by the end use of the product. Each market segment prefer different type of chickpea. For example, dried whole seed segment, split chickpea (dhal) segment, flour segment, and roasted and puffed segment. Kabuli chickpeas are in a different segment altogether with distinct preference for specific types. Preliminary results indicate that for kabuli chickpeas, large and uniform seed size; cream or white color; and easy to cook are some of the preferred traits. For split chickpeas (dhal), large and uniform seed size; light to medium brown color; thin seed coat; high recovery rate of dhal; low moisture content are

preferred. For split dal processors have to make a choice between high recovery rate on size of dhal. Processors also grade the dhal into different sizes and bold dhal sells at a premium of Rs. 2000-3000 per tonne. Pulse processors in Calcutta in West Bengal a minor chickpea growing state in India rely on imported desi chickpeas from Australia, since imported chickpeas work out cheaper than imports from major chickpea growing states in India located in the north. For roasting and puffing special varieties like Annagiri, G5, Gulabi, are preferred. Imported chickpeas are mainly used for making dhal and Australia is a major supplier. For Kabuli chickpeas Mexico, Turkey, Iran, and Australia are main suppliers.

Conclusions

It is important that breeders in Australia develop chickpea varieties to meet specific consumer needs. High quality chickpea attracts a premium. To differentiate its chickpea from those of other competitors, Australia should develop a brand name or trade- mark.

5.8. Diagnostic Analysis on Sorghum Utilization Prospects in India Completed

By A. Hall, D. Jha, and P. Parthasarathy. Rao

Background

Sorghum in India is widely perceived as a crop produced and consumed mainly by the poor. Often referred to as a poor man's crop, in the past it has been assumed that scientific research on sorghum would ultimately benefit the poor through improved food security. Research programs at ICRISAT, as well as national programs in India, have made significant advances in yield improvement and stabilization through variety enhancement. As the agenda of poverty reduction moves on from alleviating food scarcity to encompass issues of food preference, livelihood (and income) security, marketing, value added processing, and alternative utilization, the scientific agenda also needs to be re-examined. This realignment is not only necessary in terms of specific scientific research strategies, but also a more fundamental questioning of the underlying assumption that support of sorghum is analogous to the support of the poor.

In the context of providing improved options for sorghum utilization, the underlying assumptions need particularly close examination. There is significant evidence that in the past sorghum has played an important role in the marginal production environments in which the poor of India live and in the diets of both the urban and rural poor (Ryan *et al.* 1984, ICRISAT VLS Survey 1989/90, unpublished data). The development of market demand through increased utilization has been viewed as a means of supporting a crop grown and consumed by the poor. Success of such initiatives has been limited. Furthermore significant changes (declines) in both production and consumption of sorghum suggest that wider structural changes may be taking place which have more pervasive results than attempts to improve the utilization of the crop. Ultimately the rural poor may be able to follow more productive strategies with other commodities. This study sought to explore these issues.

While it seems likely that sorghum is still important to the poor in particular production and consumption niches, the overall national scenario is one of decline. Technical initiatives to support the poor through increased utilization of sorghum seem to have had insignificant impacts compared to the wider set of changes taking place. There is a clear need to establish a much broader understanding of the factors affecting both the production and utilization of the crop. As part of this process it is necessary to look much more closely at the relevance of both sorghum production and consumption to the livelihoods of the poor. This includes exploring the ways in which improved or increased utilization of sorghum will allow the crop to contribute to the sustainability of their livelihoods. The purpose of this study was to provide insight into future trends and in this way underpin future judgements on the targeting of research aimed at improving the efficiency of utilization of these crops.

Methodology

The research methodology included the following: A sample survey examining factors affecting sorghum production and consumption conducted in 42 villages. A participatory rural appraisal examining the role of sorghum in the livelihoods of the poor conducted in 11 villages. A survey of factors affecting the consumption of sorghum by the urban poor completed in 5 urban centers; and a survey of factors affecting the industrial utilization of sorghum, including a postal survey of 40 animal feed manufactures,

5 starch producers and 7 distillers and in depth discussions with 20 organisations engaged in industrial utilization of sorghum.

Results and Discussion

The rural field work component of this study has been central in drawing conclusions concerning the relative importance of sorghum, both in terms of farming systems and in terms of livelihoods. This in turn has been used to link the livelihoods of the poor with its future prospects. The sampling frame used for this rural component encompassed districts in the target states where sorghum was judged to be important in terms of production. So naturally the scenarios of sorghum production and consumption derived from these rural studies exhibit a more optimistic picture of the crop and its role in rural livelihoods than might be expected by examining all India statistics. While this may provide a rather skewed picture of sorghum in India, the results do reflect a situation that pertains in areas in the country with a rural population of 60 million people and 20 million cattle and buffaloes. The urban population adds an other 10 million people in these areas. This is a significant corpus of the world's poorest. Evidence suggests that these areas have stabilized as India's "sorghum heartland", an area where sorghum will continue to be central to rural livelihoods.

Another important issue relates to the identity of the rural poor and the implication of a commodity focused approach to poverty alleviation. It is no longer valid – if it has ever been – to consider the rural poorest in India as farmers. At best they are marginal farmers, at worst and most frequently they are landless and reliant on agricultural employment. Numerically the poor are the dominant group in rural society. Their greatest concern continues to be access to food. If the poor have land agricultural sorghum production contributes to this, but never more than partially. More usually the main contribution of agricultural production to their livelihoods is through the creation of employment opportunities. The best that agricultural development can offer them is cheap food and the means to access it.

Sorghum, and certainly *kharif* sorghum, does provide the poor with cheap food. However it is farming systems – including sorghum production – that is the greatest means of accessing food via the employment opportunities that it creates. The most important and rather intangible – and therefore underplayed -- importance of sorghum is as an input into these farming systems. The relative importance of sorghum as a source of fodder for livestock is of crucial importance to these farming systems. It is the integrated nature of these crop livestock systems that underpins the sustainability of the farming systems in the semi-arid tropics of India. Sorghum therefore underpins the system that is most important in allowing the poor access to employment and therefore food. This systemic importance, regardless of any other concerns, is a fundamental reason for sustaining the presence of sorghum in the cropping patterns of the semi-arid tropics.

Coming to more specific issues, quite distinct scenarios have emerged in the India sorghum sector for the *rabi* and the *kharif* crop. Access of the poor to food in *rabi* areas is predominately a productivity issue. Without a major breakthrough in yield in these production environments, the poor will continue to have difficulty access their preferred food, either through their own production or through the availability of affordable sorghum grain in the market. The caveat to this suggested thrust is that productivity gains should not be at the expense of grain quality and fodder quality and quantity. *Rabi* sorghum will continue as human food.

The *kharif* sorghum scenario is one in which productivity gains have already been relatively successful and this has provided both the rural and urban poor with cheap food. Unfortunately this has often been at the expense of grain quality either due to taste or due to its susceptibility to quality deterioration, both pre and post-harvest, as well as fodder quality. These two factors need to be given much closer attention in crop improvement programs. In part these quality factors have reduced the price of grain and this has aided the development of an industrial demand for the commodity. There is clear segmentation of demand for both food and non-food uses for animal feeds, particularly poultry, but also grain alcohol and starch. This has developed a market for the lowest priced and poorest quality grains

While the systemic importance of sorghum has been highlighted, what are the likely mechanism for maintaining the position of the crop in farming systems? Agricultural and trade policy reforms will at worst be neutral and at best supportive of the crop to some extent. Increasing rural labor shortages will also tend to favor the crop due to its relatively low labor demands. The competitive position of the crop – profitability – will need continued support from demand for the commodity at a level at least equal to that at present. Rural household demand for grain will at best remain stable and at worst show a steady decline. The same is also true for urban demand for food, with declines likely to be if anything more substantial. However industrial utilization of *kharif* sorghum is projected to grow very strongly. The target for post-harvest research should therefore be *kharif* sorghum and its industrial utilization. While *rabi* sorghum should be given less importance, post-harvest concerns should be should still be leveraged through *rabi* sorghum crop improvement programs, particularly with respect to grain and fodder quality.

Of the three target industrial sectors identified as being significant in the utilization of sorghum animal feeds (particularly poultry) and grain alcohol should be the target. For the starch industry, sorghum has significant functional disadvantages compared to maize and cassava. The focus on the animal feeds sector should be on technical and market and institutional issues discussed in detail below. For the grain alcohol sector constraints are more likely to be on the supply side and therefore issues concerning marketing and vertical integration to link farmer with potential users are likely to be more important.

A post-harvest focus on *kharif* sorghum for industrial utilization needs to consider the following 4 elements.

Crop improvement for specific new industrial uses: *Kharif* sorghum is very clearly making the transition from a food crop to a crop used as an industrial raw material. While this does not mean that food quality should be given lower priority in crop improvement programs, variety traits for specific industrial applications need to be considered. This raises a number of institutional issues concerning the extent to which public good research should support industrial development taking place in the private sector. While it would be useful to examine the streams of benefits that this technological trajectory would produce, if the systemic importance of sorghum in farming systems is accepted, this approach would be consistent with supporting the livelihoods of the poor. However public private sector institutional linkages in improvement programmes will be critical if these research thrust is to be meaningful.

Technical constraints to increased utilization: In the animal feeds sector a number of technical constraints to increased utilization have been identified. These include tannin levels of grain, mycotoxin contamination and energy levels of different sorghum varieties. Long term, bulk storage of sorghum by

industrial users needs much closer consideration, particularly as hybrid *khariif* sorghum is likely to be the predominant grain types. Similarly long term storage options needs to be examined if sorghum is to be used in any further schemes for a decentralised public distribution system. Institutional arrangements for the scientific and technical support of these initiatives with the various stakeholder organisation involved will need to be carefully considered (see below).

Market and policy constraints: Although initial assessment of the marketing system for sorghum has indicated that it is relatively efficient and could cope with increased volumes, the levels of industrial utilization predicted suggest that this needs much closer consideration. Market infrastructure, including storage and handling, and institutional factors need much closer examination. Understanding the reason why closer integration of industrial users and sorghum producers has not occurred would be useful in this respect as the process has important synergy and poverty implications. It would also be useful to examine in more detail the way in which trade and economic liberalisation is impacting on the functioning of grain markets and the implications of this for sorghum utilization. As a word of caution, the marketing system as a crucial link between production and new source of demand for sorghum, still has the potential to emerge as a rate limiting step when pushed beyond its current functions and therefore warrants much closer attention.

Institutional constraints to the uptake of post-harvest technology: One of the key finding of this research is that increased utilization of sorghum in the industrial sector has been despite the lack of any specific technical breakthrough rather than because of it. In fact many of the persistent perceptions of the poor industrial utility of sorghum are areas of research where considerable work has already been carried out in public sector research institutes in India. There are many reasons for the divergence and weak linkages between private enterprise in India and public sector research. However it is clear that further technical research on sorghum will only be worthwhile if it is undertaken within a project structure that bridges this institutional gap and provides a more interactive approach to problem solving. This is not of case poor flows of existing knowledge to target sectors of economic activity. Rather this is case of there being no knowledge creation process which links science with these important clients. Addressing these institutional issues should be given priority. If these institutional constraints are allowed to persist, post-harvest research will become increasingly irrelevant, under exploited, poorly adopted and of little benefit to the poor of the semi-aid tropics of India.

Conclusions

As a result of this study key technical, policy and institutional constraints to sorghum utilization have been identified. Furthermore this has been achieved within the framework of exploring the relevance to the poor of improved utilization of the crop .