Evaluating ICRISAT Research IMPACT

International Crops Research Institute for the Semi-Arid Tropics

Abstract

Citation. Bantilan, M.C.S and Joshi, P.K. (eds.). Evaluating ICRISAT research impact: summary proceedings of a Workshop on Research Evaluation and Impact Assessment, 13-15 Dec 1993, ICRISAT Asia Center, India. (In En. Summaries in En, Fr.) Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 148 pp. ISBN 92-9066-302-2. Order code: CPE 091.

Research evaluation and impact assessment (REIA) at ICRISAT is recognized as an important part of research planning, and serves several functions: to quantify the impact of research products on their final clientele; to improve research planning and priority setting, given limited research resources; to develop an information and decision-support system for scientists and research managers; and to establish greater accountability with donors and funding agencies.

The workshop was attended by ICRISAT scientists from all disciplines and by representatives from public and private sector research institutions and the seed sector. This summary proceedings discusses the various research outputs from ICRISAT research, impact indicators, and other socioeconomic factors relevant to REIA. The workplans for implementing REIA, recommended at the Workshop, are also recorded.

Résumé

Evaluation de l'impact de la recherche de l'ICRISAT: comptes rendus d'un Atelier sur l'évaluation de la recherche et l'estimation de l'impact, 13–15 décembre 1993, Centre ICRISAT pour l'Asie, Inde. A l'ICRISAT, l'évaluation de la recherche et l'estimation de l'impact (REIA) jouent un grand rôle dans la planification de la recherche. Cette activité a pour objet de: déterminer l'impact des produits de la recherche sur les utilisateurs; améliorer la planification de la recherche et la définition des priorités dans le cadre des ressources limitées; élaborer un système d'information permettant la prise des décisions par des chercheurs et des directeurs de recherche; et établir un meilleur mécanisme de responsabilité financière envers des bailleurs de fonds.

Des chercheurs de l'ICRISAT provenant de toutes les disciplines et des représentants des instituts scientifiques des secteurs public et privé ainsi que des sociétés semencières ont participé à l'atelier. Ces comptes rendus examinent les divers résultats de la recherche de l'ICRISAT, des indicateurs de l'impact, et d'autres facteurs socio-économiques qui touchent au REIA. Les projets pour la mise en oeuvre du REIA, recommandés à l'Atelier, sont aussi présentés.

Evaluating ICRISAT Research Impact

Summary Proceedings of a Workshop on Research Evaluation and Impact Assessment

13-15 Dec 1993, ICRISAT Asia Center

Edited by

M C S Bantilan
and
P K Joshi

ICRISAT

International Crops Research Institute for the Semi-Arid Tropics

1994

Contents

Introduction

Workshop Overview

M C S Bantilan[1]

Introduction

Ladies and gentlemen, good morning. I would like to welcome you all to this Workshop on Research Evaluation and Impact Assessment. In a manner of speaking, the year has been a long series of meetings and discussions on research evaluation and impact assessment—held in the corridors of ICRISAT; in scientists' laboratories; in farmers' fields in India (Maharashtra, Andhra Pradesh, Gujarat, and Rajasthan) and elsewhere (Sri Lanka, Vietnam, and Indonesia); in government offices; and in the offices of the private sector seed industry. The underlying concern during all these 'mini-workshops' these past 12 months or so has been the question of *the impact of our research vis-a-vis ICRISAT's mandate.* You have all been a part of the process of evolving an answer. It is fitting, therefore, that we all gather together for a culminating activity—to formalize and substantiate our efforts over the year to develop a comprehensive and systematic system of Research Evaluation and Impact Assessment (REIA).

Why REIA?

Investment in agricultural research has diverse goals, but is ultimately targeted at economic growth and social welfare. Several studies in the past have confirmed that returns on investment in agricultural research are quite high. We believe that ICRISAT's research efforts on its mandate crops—sorghum, millets, chickpea, pigeonpea, and groundnut—are responsible for a large number of tangible and intangible benefits at different levels, wherever these crops are grown.

It is important, for several reasons, to undertake a systematic and comprehensive impact assessment of technologies and/or information generated by ICRISAT. First, the results of such an assessment will provide scientists and research managers with a basis for setting priorities among alternative research options and deciding on resource allocations. Secondly, the assessment will provide feedback to researchers regarding their clientele's needs, and thus improve the design of target-oriented research. Thirdly, it will demonstrate to donors, in quantitative and qualitative terms, that investment in ICRISAT research does indeed have an impact in farmers' fields; this will help maintain or enhance donor support for the Institute.

1. Socioeconomics and Policy Division, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.

Workshop objectives

This workshop was organized with three broad objectives:

- To discuss a framework for research evaluation and impact assessment (REIA) that has been developed by economists and crop scientists from various disciplines at ICR1SAT;
- To draft a workplan based on this framework;
- To identify the role of participating scientists in the REIA work program.

The workshop is thus designed to enable us to clearly lay out a phased plan for economic assessment—for the next year, for the next 2 years, for the next 5 years and soon. We will subsequently draft an integrated workplan covering a range of research products, with appropriate assessment methods (e.g., short- or long-term) for each product.

Objectives of the workplan

Our first objective is to find the best way to document—and quantify—ICRISAT's achievements. Another objective is to develop a decision-support system for setting research priorities at ICRISAT. This system will support decision-making for the whole organization—for research management and for scientists.

In effect, what we are trying to do is to institutionalize the process of impact assessment at ICRISAT. To do this, we need to develop a database to support our information generation system; we need to develop effective information generation procedures that will produce the kind of information our decision-makers require—research managers making policy decisions, and scientists setting priorities among alternative research options. Finally, we have to find ways to ensure that impact assessment remains a permanent and integral part of research planning at ICRISAT.

I hope you all agree with me that a properly planned REIA analysis can only benefit the scientist, and therefore the farmer as well. The analysis may be relatively easy for some projects, and difficult for some others (as we shall see later). But it essential in either case, and over the next three days we will try to identify the right approach to impact assessment for different types of research outputs.

Again, welcome to the REIA workshop.

Keynote Address

J G Ryan[1]

Introduction

Welcome to the Research Evaluation and Impact Assessment (REIA) Workshop, which is the initiative of Dr Ma Cynthia S Bantilan and her colleagues in the new Socioeconomics and Policy Division at ICRISAT Asia Center.

This workshop is timely; resources for national and international research have been severely constrained in recent years despite the very high rates of return (often in excess of 30% per year) that have been demonstrated on investment in agricultural research. Such high rates of return indicate an under-investment of resources for agricultural research.

We need more effective assessments of the contributions of agricultural research to societal objectives for two reasons:

- To marshall more research and development (R and D) resources; this might be termed the focus on the external environment;
- To ensure that the dwindling resources are used most effectively within the organization, i.e., a focus on the internal environment.

In this process the respective roles of the various actors in the global R and D system need to be kept in mind.

Assessing individual contributions in collaborative research

The national agricultural research systems (NARS) are becoming stronger, especially in Asia, and their relationships with international agricultural research centers (IARCs) are continuing to evolve. Collaboration and partnerships to exploit complementarities and comparative advantages are becoming the norm. This implies that in evaluating the benefits of agricultural R and D activities, their 'jointness' should be emphasized.

With the likelihood that protection of intellectual property rights will be strengthened in the coming years, the relationships between the private sector and the national and international public sector R and D institutions will change. These changes will be most evident, at least initially, in the area of plant breeding. These will in all likelihood reinforce the decision at ICRISAT to move away from the release of finished products. This will make it that much more difficult to assess the respective contributions of the IARCs, publicly-funded institutions, and the private sector to the ultimate impact of their work on farmers, workers, and consumers.

1. Director General, ICRISAT, Patancheru 502 324, Andhra Pradesh, India.

I would contend that separately attributing these contributions is not necessary either, as we are all partners in the global agricultural R and D system. However, if we all believe, as I think we do, and as evidenced by the representation of the three types of actors here today, that there are interdependencies amongst us, and that we therefore have a vested scientific and economic interest in continuing collaboration for our mutual benefit, we must assist each other in articulating, measuring, and communicating the joint impacts of our work. As IARCs move further upstream in their research focus, there is a danger that their capacity to document their contributions at the farm level will erode. The causalities become blurred and to try and unravel them becomes difficult; and the process risks damaging the growing sense of partnership amongst the actors involved.

An increasing proportion of IARC 'outputs' will be in the form of intermediate products—diagnostics, probes, parental lines, segregating materials, management practices for soil, water, and nutrients, socioeconomic information and policy advice, etc. These and their associated information and technology exchange activities, we believe, are essential ingredients in NARS and private/public sector research programs, which are more applied and adaptive in nature. The IARCs do not have a comparative advantage in the design of finely tuned production technologies; the NARS do. We of course have a role in helping to develop methodologies to assist in their development and adoption. For example, the farming systems approach to research, on-farm research, and research methods that stress farmer participation, are all an integral part of ICRISAT programs.

For all these reasons a joint approach to the assessment of impact is crucial to the continuing viability of the global agricultural research system. To move ahead in this way requires goodwill, cooperation, and understanding while respecting the need for degrees of confidentiality in the provision of proprietary information. I see no inevitable conflict in the pursuit of our individual mandates and the conduct of joint impact assessments if we acknowledge the complementarities among us. If one cog in the machine fails then we all stand to lose!

Impact assessment criteria

Impact assessment is not a one-off exercise. To be effective it must involve both *ex ante* and *ex post* elements in what Horton refers to as 'Operational Impact Assessment'. This means that research projects begin with a clear projection of research opportunities and potential for impact, and that these are continuously monitored, evaluated, and refined using milestones laid out in the proposals. Mid-term corrections are effected as required using multidisciplinary peer review mechanisms and feedback from farmers and other partners.

In all of this we must not so stifle scientific initiative that serendipity, which can play a major role in achieving impact (sometimes in unanticipated directions), is suppressed. By ensuring that priorities are set on the main game, however, we maximize the chances of serendipitous findings making a significant scientific and socioeconomic impact.

Not all impact assessment needs to be formal in nature. There is considerable value in coffee discussions, seminars, conferences, workshops and the like, not to mention working together in farmers' fields. These can often highlight why the projected payoffs in *ex ante* assessment were not realized when *ex post* evaluations were conducted. Sometimes the reasons can be the vagaries of the scientific games of chance we play in research; sometimes it can be because of poor science or research management; and often it is because rural infrastructure was not adequate. In each case, there will be implications for future R and D planning. The formal *ex ante* and *ex post* assessments can at best highlight the discrepancies. Drawing out the implications requires further investigation.

There are many challenges ahead for those involved in research evaluation and impact assessment. Some of these are:

Sustainability-related research. How do we assess the socioeconomic value of research on sustaining the natural resource base? Is it possible to assess such research in the same manner as we do for commodity research? Is soil erosion research, which helps to ensure the future productivity of cropping systems, likely to be in demand by future generations? If so, could we estimate by how much cropping systems productivity in that future would be increased (or maintained) and use this as one measure of the likely benefits of soil erosion research? Of course this would have to be weighed against the extent to which erosion from one site transfers soil to other sites in the lowlands and deltas, with the potential for both positive and negative externalities. There may be as many implications for distribution of socioeconomic gains and losses in this type of research as there are in the benefit-cost calculus per se!

Socioeconomics research. How do we assess the payoffs from socioeconomics and policy research? We economists like to believe we can advise research managers on the allocation of resources among commodities and regions, but when it comes to allocation among disciplines, especially the social sciences, we have less to say. This was brought home to us recently as we developed our medium term plan (MTP). While the economists played a leadership role in this, they were not able to calculate an index of priority for socioeconomics themes that was consistent with those developed to rank research themes in crop improvement and resource management.

Trade-offs between objectives. How do we factor into both *ex ante* and *ex post* impact assessment measures that embrace the multiple goals and research/funding priorities of nations and donors? As Scobie points out, research can be a blunt instrument for attaining societal objectives other than economic growth. However, the relative emphases on commodities and regions can usually be couched in terms of efficiency-equity trade-offs requiring weights to be assigned. Similarly a focus on integrated pest management may or may not entail trade-offs between efficiency and environmental sensitivity.

Research priority setting at ICRISAT

We used four criteria in our MTP to endeavor to accommodate concerns about efficiency, equity, sustainability, and internationality. There were data deficiencies and conceptual and analytical problems we had to contend with. No doubt my colleagues will discuss these with you during the course of the next few days and beyond; our partner institutions probably have confronted the same challenges. I look forward to your deliberations on these and the other issues I have raised.

We chose to make the choices about our future research portfolio in the MTP analytical, interactive, and transparent to all our stakeholders. We constructed a composite index, involving these four criteria, to rank the 110 research themes we identified, so that stakeholders could clearly judge the opportunity costs of alternative funding decisions. We believe this is the appropriate approach to take in *ex ante* priority assessment. We are now in the process of operationalizing the plan into research projects which attempt to exploit ICRISAT's comparative advantage and global mandate, as well as the economies of scale obtained through multiple research programs at a number of locations.

To do this we have decided to emphasize the project as the basic unit of research management in the future and to use a matrix mode of management to ensure a flexible approach to the delivery of intermediate and final outputs. The two axes of the matrix will be Regions on the one hand (and production systems within them) and seven Research Divisions on the other. I emphasize that the ICRISAT mandate has not changed as a result of these changes; only the way in which we will array our resources to fulfill that mandate. We believe that the new arrangements best position ICRISAT to respond to the dynamic external environment we face. The expectations of our partners in the public and private sector R and D institutions, some of which are represented here today, have played a major part in fashioning the new ICRISAT. We look forward to working together to ensure that our partnerships reap the rewards expected by our stakeholders, be they tax payers or investors, because unless we do, their future support will be found even more wanting than it is today.

Germplasm Management and Enhancement Research

Management of Plant Genetic Resources at ICRISAT

M H Mengesha and S Appa Rao[1]

Introduction

One of the major objectives of ICRISAT is to serve as a repository for the world germplasm collections of its five mandate crops, and of six species of minor millets. The assembly and characterization of germplasm, preliminary to its utilization for crop improvement, is the starting point for much of agricultural research work. At ICRISAT, this function is served by the Genetic Resources Division, which is responsible for collection/assembly, maintenance/conservation, evaluation/characterization, and distribution of germplasm. These activities create impact in several ways:

- By conserving genetic diversity among crop species and their wild relatives;
- By evaluating and characterizing a wide range of material, thus facilitating its use by other researchers (e.g., in breeding for higher yields or resistance to stresses);
- By providing promising or potentially useful material to researchers worldwide, and acting as a focus (through participation in networks) for the exchange of genetic material among NARS;
- By collaborating with NARS on collection missions and training programs/workshops, thus strengthening NARS capabilities in the areas of collection and characterization.

Collection and Evaluation

The ICRISAT genebank has assembled 109 847 accessions, consisting of 33 766 sorghum, 24 199 pearl millet, 16 878 chickpea, 12 393 pigeonpea, 13 949 groundnut, and 8 662 of minor millets (finger, foxtail, proso, little, barnyard, and kodo millets). These accessions originated from 127 countries, the majority of which are in Asia and Africa. ICRISAT has launched several successful germplasm collection missions in collaboration with international, regional, and national agencies.

The assembled germplasm is evaluated at ICRISAT Asia Center, Patancheru, for 30-35 internationally accepted traits, during the rainy and postrainy seasons. Sources of resistance to biotic and abiotic stress factors are identified by a multidisciplinary team of scientists. Locally adapted germplasm is identified through regional or multilocational evaluation at or near the place of origin or utilization; and under good management conditions, to determine the yield potentials. All the evaluation and passport data of the conserved germplasm are documented on computer in machine-readable form, which facilitates quick retrieval of information.

1. Genetic Resources Division, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.

Table 1. ICRISAT germplasm accessions or selections released as superior varieties in different countries, 1980-93.

Accession number	Country of origin	Country of release	Release name	Year of release
Sorghum				
IS 8965	Kenya	Myanmar	Shwe-ni 1	1980
IS 2940	USA	Myanmar	Shwe-ni 2	1981
IS I8758	Ethiopia	Burkina Faso	E-35-1	1981
IS 18484	India (AICSIP)	Honduras	Tortillerio	-
IS 9302	South Africa	Ethiopia	ESIP 11	1984
IS 9323	South Africa	Ethiopia	ESIP 12	1984
IS 30468	Ethiopia	India	NJ 2122 (ET-1966)	1990
IS 9468	South Africa	Mexico	-	1990
IS 13809	South Africa	Mexico	-	1990
IS 9321	South Africa	Mexico	-	1990
IS 9447	South Africa	Mexico	-	1990
IS 2391	South Africa	Swaziland	SDS 1513	1990
IS 3693	USA	Swaziland	SDS 1594-1	1990
IS 9830	Sudan	Sudan	Mugawim Buda-2	1991
IS 3924	Nigeria	India	Swarna	1991
IS 35412	Sudan	India	CS 3541	1992
IS 3687xIS 1151[1]	USA, India	India	148/168	1992
IS 3922xIS 1151[1]	Nigeria, India	India	604	1992
IS 3922xIS 1152[1]	Nigeria, India	India	302	1992
IS 2954xIS 18432[1]	USA, India	India	370	1992
IS 2950xIS 1054[1]	USA, India	India	R 16	1992
Pearl millet				
IP 17862	Togo	India	ICTP 8203	1988
Chickpea				
ICC 552[3]	India	Myanmar	Yezin 1	-
ICC 4951[3]	India	Myanmar	ICC 4951	-
ICC 6098[4]	India	Nepal	Radha	1987
ICC 8521	Italy	USA	Aztee	-
ICC 8649	Afghanistan	Sudan	Shendi	1987
ICC 11879	Turkey	Turkey	-	1986
		Algeria,	-	1988
		Morocco	-	1987
		Syria	Ghab 1	1982
ICC 13816	USSR	Algeria,	Yialousa	1984
		Cyprus,	-	-
		Italy,	Sultano	1987
		Syria	Ghab 2	1986
ICC 14911	USSR	Turkey,	-	1986
		Morocco	-	1987
ICC 4923	India	AP, India	Jyothi	1978

Continued

Table 1. Continued

Accession number	Country of origin	Country of release	Release name	Year of release
Pigeonpea				
ICP 7035	India	Fiji	Kamica	1985
ICP 8863	India	India	Maruti	1985
ICP 9145	Kenya	Malawi	Nandolo wa Nswawa	1988
ICP 14770	India	India	Abhaya	1989
ICP 11384 (ICPL 332)	Nepal	Nepal	Bageswari	1992
ICP 11543	India	India, Myanmar	Pragati	1992
ICP 11605	India	India	Jagriti	
ICP 11605[1]	India	Australia	Hunt	
ICP 11605[1]	India	Indonesia	Megha	
ICP 11605[1]	India	Australia	Quantum	
ICP 11605[1]	India	Australia	Quest	
ICP 6997	Nepal	Rampur Rhar	1992	
ICPL 151[1]	India	India	Jagriti	1990
Groundnut				
ICG 7886	Peru	Jamaica	Cardi-Payne	1987
ICG 7794	USA	Ethiopia	-	1989
ICG 273	Argentina	Ethiopia	Sedi	1994
Finger millet				
IE 2929	Malawi	Zambia	Lima	1987

1. Selections from crosses.
2. Converted zerazera.
3. Twin podded.
4. Wilt resistant.

All the assembled germplasm is conserved in the ICRISAT genebank, both in medium-term (4°C, 20% relative humidity) and long-term (-18°C) storage chambers which meet international standards. During the process of rejuvenation and seed increase we follow appropriate pollination control method (e.g., selfing or controlled crossing). To minimize genetic drift, we use large populations of 100-200 plants per accession during each rejuvenation.

To safeguard against the possible loss of germplasm due to unforeseen reasons, we have initiated a plan to establish duplicate conservation centers.

Maintenance and conservation

Scientists in NARS and international organizations consider the ICRISAT genebank to be a reliable and dependable source of germplasm and information. So far, we have supplied 1 094 849 samples, which include 510 170 samples to scientists in ICRISAT, 307 709 samples in India, and 276 970 in other countries. They include 237 265 samples of sorghum, 89 975 of pearl millet, 99 048 of chickpea, 51 507 of pigeonpea, 70 142 of groundnut, and 36 742 of minor millets. This activity is one of ICRISAT's most valuable long-term contribution to NARS crop improvement programs (especially since no other center is involved in large-scale distribution of germplasm of these crops), where it has had considerable impact. The major users are scientists in NARS, international organizations, universities, and private and public sector organizations.

Germplasm evaluation by ICRISAT has resulted in the identification and direct release of several superior genotypes as varieties; 15 in sorghum, 9 in chickpea, 8 in pigeonpea, 1 in pearl millet, and 3 in groundnut, and 2 in finger millet (Table 1). Some high-performance genotypes have been found suitable for release in several countries (e.g., ICC 11879, ICC 13816). Germplasm is also used as parents in crossing programs, and a large number of superior cultivars have been produced. Another important activity of the Genetic Resources Division is the development of genepools. We are currently developing four pearl millet genepools—short duration, large grain, high tillering, and large spike. These are expected to be an important addition to NARS breeding program resources.

Genetic Enhancement Research on Sorghum at ICRISAT Asia Center, 1972-92

Belum V S Reddy and J W Stenhouse[1]

Introduction

Sorghum is a staple food crop in India and large parts of Africa, and an important feed and forage crop in other parts of the world. The total area under sorghum has been stable, from 45.1 million ha during 1979-81 to 45.2 million ha in 1992. However, there has been a large (45%) increase in the area of cultivation in Africa over this period. In all other regions, the area under sorghum cultivation has declined, though the magnitude of the decline differs from region to region.

ICRISAT aimed in the past at developing screening techniques, breeding improved resistant sources and varieties, and breeding high-yielding populations, varieties, and hybrids. Thus, the emphasis was on finished products for the farm.

However, the emphasis has now changed from breeding finished products to breeding parental lines and conducting strategic research. Accordingly the objectives of the program at present are: breeding resistant seed parents and restorer lines, developing specific new gene pools and novel plant types, identifying and using molecular markers in breeding, and understanding resistance mechanisms and their genetics.

Released cultivars

The impact of ICRISAT's sorghum research is manifested at organizational levels, research program reviews, and project formulations in NARS. Its impact is also seen at farm level through the release of its products. Table 1 lists released varieties/hybrids that were developed at ICRISAT Asia Center (IAC).

ICSV 1 was released in India in 1984 as CSV 11, and in 1989 in Malawi as SPV 351. It gave grain yields of 3.3 t ha^{-1} in All India Coordinated Sorghum Improvement Project (AICSIP) trials during 1980-85, matures in 110-115 days, and grows to a height of 1.6-1.9 m. ICSV 112, another high-yielding variety (3.4 t ha^{-1} in AICSIP trials, 1982-87), has been released in India, Zimbabwe, Mexico, and Nicaragua. It matures in. 115-120 days, and grows to a height of 1.7-1.8 m. ICSV 145, released in India as SAR 1 in 1988, is a high-yielding *Striga*-resistant variety that matures in 105-110 days and grows to a height of 1.8-2.4 m. It was the highest-yielding entry in AICSIP *Striga* trials, where it supported only 3 *Striga* plants m^{-2}, compared to 90 plants m^{-2} for CSH 1. ICSH 153 is a high-yielding hybrid (4.1 t ha^{-1} in AICSIP trials,

1. Genetic Enhancement Division, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.

Table 1. List of released sorghum varieties and hybrids developed at ICRISAT Asia Center.

Variety/ Hybrid	Pedigree	Research initiated	Product identified	Year of release/ country
ICSV 1	SC108-3 x CSV 4	1976	1980	1984 India, 1989 Malawi
ICSV 2	SC108-4-8 x CSV 4	1976	1980	1983 Zambia
ICSV 112	[IS12622C/555) (IS13612C/2219b)/E35-l)]	1975	1982	1987 India, 1985 Zimbabwe, 1989 Mexico, 1990 Nicaragua
ICSV 145	555 x GPR 148	1977	1982	1988 *Striga*-endemic areas in India
ICSH 153	296A x MR 750	1976	1981	1986 India
SRN 39	GPR 148 x Framida	1976	1979	1991 *Striga*-endemic areas in Sudan, 1993 Niger
M 90393	(GPR 148 x E35-l)x 3541	1976	1980	1992 Sudan
M 62641	(SC108-3xCS3541)xE15-5	1977	1979	1989 Mexico
M 90812	IS12611 x (Bulk 'Y' x GPR 165)	1976	1980	1991 Mexico
M 91057	(GPR 148 x E35-1) x CS 3541)	1976	1980	1991 Mexico
M 62650	(SC 423 x CS 3541) x E35-1	1977	1979	1985 Honduras
M 90975	GPR 168 x SC 170	1976	1980	1985 Guatemala

1981-87) developed for rainy-season cultivation, and released in India in 1986 as CSH 11. It matures in 105-115 days and grows to a height of 1.6-1.9 m.

NARS collaboration

In addition to the direct release of ICRISAT-bred material, several open-pollinated varieties and hybrids have been developed and released by NARS (or marketed by seed companies) in different countries, using ICRISAT material. These are listed in Table 2.

India. NTJ 2, a variety developed from an ICRISAT-supplied zera zera landrace line (IS 30468 from Ethiopia), was released in 1990 in Andhra Pradesh. CSH 14 (SPH 468), developed by the Punjabrao Krishi Vidyapeeth, Akola, and released in 1990, has an ICRISAT-bred maintainer line (possibly ICSB 35) as a one-eighth parent. Three varieties (PKH 400, a dual-purpose cultivar, SPV 1140, and SPV 1201) developed by the Marathwada Agricultural University, Parbhani, contain ICRISAT-bred materials. ICSV 745, developed in collaboration with University of Agricultural Sciences, Dharwad, Karnataka, was released for cultivation in midge-prone areas in Karnataka.

Table 2. List of sorghum varieties and hybrids developed by NARS using materials developed at ICRISAT Asia Center.

Variety/Hybrid	Pedigree	Research initiated	Product identified	Year of release/ country
HD 1[1]	AT x 623 x Karper-1597	1978	1980	1983 Sudan
ICSV 197	IS 3443 x DJ 6514	1979	1983	1986 midge-prone areas in India
ICSV 745	ICSV 197 xA6250	1983	1989	1993 midge-prone areas in India
ICSH 110	296 A x MR 836	1976	1983	1988 India
Melkamesh	Diallel pop. 7-8	1976	1978	1979 Ethiopia
	SC 108-3 x CS 3541	1976	1980	1986 Ethiopia
SEPON 82	M 90038	1976	1982	1993 Niger
SRN 39	ICSV 1007 BF: CSV 5 x Framida	1977	1986	1993 Niger 1991 Sudan
NTJ-2	A landrace supplied from ICRISAT (IS 30468)	1985	1989	1990 A.P., India
Liao-4	SPL 132 A female is used	1981	1986	1988 China
CSH 14	ICSB 35 is a great grandparent	1981	1985	1993 India
PKH 400	Parents from ICRISAT materials	1985	1990	1993 India
PSH 8340	Parents from ICRISAT materials	1985	1990	1993 India
MLSH 36	Parents from ICRISAT materials	1985	1990	1994 India
PJH 55	Parents from ICRISAT materials	1985	1990	1993 India
PJH 58	Parents from ICRISAT materials	1985	1990	1993 India
JKSH 22	Parents from ICRISAT materials	1985	1990	1993 India
JKSH 27	Parents from ICRISAT materials	1985	1990	1993 India
Tropical 401	Population derivative	1985	1990	1991 Mexico
ICSV 1	SC108-3 x CSV 4	1976	1980	1989 Malawi

1. Developed in ICRISAT-East African Sorghum Program, Sudan.

During 1991-93, the Pro Agro Seeds Company, India, produced seed of two hybrids: 27.6 t of PSH 8340 and 3 t of PSH 8350. A new hybrid, PSH 91009, is in the pipeline for seed multiplication. Five tons of seed of two hybrids, JKSH 22 and JKSH 27, were produced in 1993 by JK Seeds, India, for on-farm testing. Eighty tons of the hybrid MLSH 36 were produced for marketing by Mahendra Hybrid Seeds Company, India in 1993. Two hybrids (PJH 55 and PJH 58) produced by Hindustan Lever Ltd, India performed significantly better than other hybrids and varieties in AICSIP trials in 1992.

El Salvador. The variety ISIAP Dorado selected from an ICRISAT-bred line, was released in 1993. AGROCONSA-1, a hybrid made from an ICRISAT-bred male parent, was released in 1987.

China. Liao 4, a hybrid developed using SPL 132 A as the female parent, was released in 1988. Two other hybrids (Liaoning Hybrids 1 and 2) were developed using ICRISAT-bred female lines, and distributed to farmers in 1993.

Impact assessment targets

The impact of ICRISAT's sorghum research can be assessed in various ways:

- Varieties and hybrids directly released (e.g., ICSV 112 in India and other countries, ICSH 153 in India);
- Improved resistance sources for the major yield-limiting factors;
- Collaborative research products (ICSV 745 released in Karnataka, HD 1 in Sudan, SRN 39 in Sudan and Niger);
- High-yielding seed parents, restorers, and varieties used as parents by NARS leading to the release of cultivars (e.g., NTJ 2 in Andhra Pradesh, India; ISIAP Dorado and AGROCONSA-1 in El Salvador, CSH 14 in India, Liao 4 in China);
- Research seed samples supplied to NARS scientists on specific request. For example, 55 breeders' seed and 40 102 research seed samples were supplied from IAC during 1990-92. In addition, other ICRISAT centers have also supplied seed samples of improved genotypes.
- Several important screening technologies developed by ICRISAT, and used by NARS researchers worldwide. These include screening methods for breeding for resistance to various biotic (grain mold, anthracnose, downy mildew, ergot, leaf blight, shoot fly, stem borer, midge, head bug, and *Striga*), and abiotic (moisture deficiency) stresses;
- Several breeding methods and concepts developed/demonstrated. These include: the option to use hybrids in a postrainy season breeding program; tall male-sterile lines for use in forage and postrainy season sorghums; methods to produce grain mold resistant hybrids; methods to overcome defects in otherwise heterotic parents; family as a unit of selection when resistance is the criterion for selection; season-based selection and the resistance index method for breeding for such quantitative traits as resistance to shoot fly/stem borer; methods of breeding resistant male-sterile lines, etc.
- ICRISAT scientists have also gathered considerable information on genetics and resistance mechanisms (e.g., to shoot fly and midge).

Recommendations on impact assessment

Five cultivars are recommended for impact/constraint analysis. In the first phase, NTJ 2, CSH 14, and ICSV 745 may be used as targets to assess the impact of ICRISAT's sorghum improvement program, and ICSH 153 and ICSV 112 for constraint analysis. Resources permitting, the analysis could be extended to other cultivars or technologies. The change in research emphasis at ICRISAT, as described earlier, will lead to the development of a different range of products and technologies. The impact of these products may be seen 8-10 years from now.

Genetic Enhancement of Pearl Millet at ICRISAT

K N Rai and C T Hash Jr[1]

Introduction

A number of important constraints limit pearl millet production in the semi-arid tropics: low grain-yield potential of unimproved cultivars, drought, downy mildew, smut, ergot, and rust in India and these factors, along with *Striga,* stem borer, and head miner, in West Africa. These constraints can be alleviated to varying degrees by genetic enhancement. Based on such considerations as relative severity and complexity of various constraints, genetic variability for various traits available in the germplasm, likely effectiveness of screening methods, availability of resources, NARS needs, and ICRISAT's comparative advantages over NARS in specific areas, genetic enhancement research on pearl millet at ICRISAT began with the following objectives:

- Greater emphasis on applied, rather than basic, research;
- Genetic enhancement for grain yield and downy mildew resistance and exploratory research on genetic enhancement for ergot, smut, and rust resistance and drought tolerance;
- Equal emphasis on the development of finished products (cultivars) and improved breeding materials/parental lines;
- Development of improved breeding and screening methodologies as an integral part of applied research.

In recent years, there has been a considerable improvement in the research capability of NARS, especially on the Indian subcontinent. This has led to the reordering of ICRISAT's priorities as follows:

- Shift in emphasis towards strategic research;
- Continued emphasis on grain yield and downy mildew resistance;
- Almost all efforts directed towards the development of improved breeding materials/parental lines (except for a few experimental varieties developed in partnership with NARS);
- Further refinement of breeding and screening methodologies, including the application of biotechnology;
- Relatively greater emphasis than in the past on genetic enhancement for arid environments.

1. Genetic Enhancement Division, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh India.

Released cultivars

Five open-pollinated varieties and four hybrids developed at ICRISAT Asia Center (IAC) have been released during 1982-93 by the Indian national program. Some of the open-pollinated varieties have also been released in southern Africa (Table 1).

Table 1. Released pearl millet varieties and hybrids bred at ICRISAT Asia Center.

Variety/ hybrid	Pedigree	Research started	Product identified	Product released
Varieties				
WC-C75	7 full-sibs of World Composite	1971	1976	1982[1]
ICMS 7703	7 inbreds: Ind. x Afr. crosses	1974	1977	1985
ICTP 8203	5 S_2 progenies of a Togo landrace	1981	1983	19882
ICMV 155	59 S_1 progenies of NELC	1978	1985	1991
ICMV 221	124 S_1 progenies of BSEC	1985	1988	1993
ICMV 82132	5 S_1 progenies of SRC	1979	1982	1989[3]
ICMV 88908	Mass-selected (BSEC x ICMV 87901)	1985	1988	1990[4]
Hybrids				
ICMH 451	81AxLCSN72+...	1975	1981	1986
ICMH 501	834A x (B 282 x 3/4EB-100) + ...	1978	1981	1986
ICMH 423	841AxEC211-l+...	1974	1978	1988
ICMH 356	ICMA 88004 x (B 282 x J 104) + ...	1981	1988	1993

1. Released as ZPM - 871 in 1987 in Zambia.
2. Also released in 1989 as PCB 138 in Punjab and as Okashana 1 in Namibia.
3. Released as Kaufela in 1989 in Zambia.
4. Released as Okashana 1 in Namibia in 1990.

WC-C75 was released for cultivation in all millet-growing areas in India, and is now the most widely grown open-pollinated variety in the country. It gave 99% of the grain yield and 120% of the dry stover yield of the then most widely grown hybrid (BJ 104) in All India Coordinated Pearl Millet Improvement Project (AICPMIP) trials. WC-C75 is also highly resistant to downy mildew (2.4% disease incidence compared to 10.1% on BJ 104 in disease nurseries). During the period 1984-92 it was sown annually on an estimated 0.6-1.2 million ha without any significant decline in downy mildew resistance. WC-C75 was also released as ZPM - 871 in Zambia.

ICMV 155 is a potential replacement for WC-C75, with similar height, maturity period, panicle characteristics, and downy mildew resistance, and superior grain and stover yields. ICTP 8203 is distinctly different from WC-C75; it is a large-seeded open-pollinated variety that matures earlier, and peforms better under terminal drought stress. It is specifically adapted to peninsular India and was released for cultivation in Maharashtra and Andhra Pradesh, where it was estimated to have been sown on 0.6-1.0 million ha annually during 1989-92. It was later released as

Okashana 1 in Namibia. ICMV 88908, with plant and grain characters similar to those of ICTP 8203 but higher grain yield, was also released as Okashana 1. ICMH 451 (highly resistant to downy mildew) is probably the most widely grown pearl millet hybrid in India (0.6 to over 1 million ha annually since 1988). In AICPMIP trials, it gave 37% more grain yield and 21% more dry stover yield than BJ 104, and proved highly resistant to downy mildew (1.3% disease incidence compared to 35.5% on BJ 104).

Twelve open-pollinated varieties developed by ICRISAT's regional programs in Africa have been released, mostly in West Africa (Table 2).

Table 2. Released pearl millet varieties developed by ICRISAT'S African Regional Programs.

Variety	Bred at	Released in
ITMV 8001	Tarna, Niger	Niger, Chad
ITMV 8002	Tarna, Niger.	Niger
ITMV 8304	Tarna, Niger	Niger
IBV 8001	Bambey, Senegal	Senegal
IBV 8004	Bambey, Senegal	Senegal
IBMV 8401	Bambey, Senegal	Senegal
IKMP 1	Kamboinse, Burkina Faso	Burkina Faso
IKMP 2	Kamboinse, Burkina Faso	Burkina Faso
IKMV 8201	Kamboinse, Burkina Faso	Burkina Faso
IKMV-IS 88102	Kamboinse, Burkina Faso	Burkina Faso
SDMV 89004[1]	SADC/ICRISAT	Zimbabwe
Ugandi[2]	Serere, Uganda	Sudan

1. Released as PMV 2.
2. Serere Composite 2 developed at Serere Research Station, Uganda and introduced in Sudan by ICRISAT.

ICRISAT-NARS collaboration

Several cultivars bred by NARS from ICRISAT-developed parental materials have been released in India (Table 3). These are mostly hybrid parents, especially male-sterile lines. In addition, several hybrids bred and sold by private seed companies are based on ICRISAT-bred male-sterile lines. The main features of these parental materials—and hybrid releases based on them—are their high grain yields and downy mildew resistance, the two thrust areas of our research. Some of the cultivars also have high fodder yields or large seeds. MLBH 104, RHB 30, and the HHB-series hybrids have good grain yields combined with short duration and good tillering ability (Table 4). Some of the parental lines (842A and 843A) developed at and obtained from Kansas State University, USA, have been widely used for their large seed size, short duration, and good combining ability rather than for high grain yield and downy mildew resistance.

Table 3. Released NARS-bred pearl millet varieties and hybrids based on parental materials developed at ICRISAT Asia Center (IAC).

Variety/ hybrid	Bred at[1]	Year of release	IAC parental material	
			Identity	Features
Varieties				
HC 4	HAU	1985	WC[2] progenies	High GY and DMR[3]
PCB 141	PAU	1993	IAC varieties	High GY and DMR, large seeds
RCB-IC 9	RAU-IAC	1990	85 S_1 progenies of IVC[4]	High GY and DMR
Hybrids				
HHB 50	HAU	1987	81A	Good GY and DMR
HHB 60	HAU	1988	81A	Good GY and DMR
HHB 67	HAU	1990	843A	Short-duration, large seeds
HHB 68	HAU	1993	842A	Short-duration, large seeds
MLBH 104	Mahendra	1991	Pollinator	?
Pusa 23	IARI	1987	841A	Good GY and DMR
Pusa 322	IARI	1993	841A	Good GY and DMR
RHB 30	RAU	1991	843A	Short-duration, large seeds

1. HAU, PAU, RAU = Haryana, Punjab, Rajasthan Agricultural University. Mahendra = Mahendra Hybrid Seed Company (private sector), IARI = Indian Agricultural Research Institute.
2. WC = World Composite.
3. GY = grain yield, DMR = downy mildew resistance.
4. Inter-Varietal Composite.

Of the varieties released (bred at IAC or by NARS from ICRISAT-developed parent materials) WC-C75, ICMS 7703, ICMV 155, and RCB-IC 9 were released for cultivation throughout India, and four others for cultivation in specific areas: ICMV 221 for areas throughout India with mean annual precipitation less than 400 mm, ICTP 8203 for Maharashtra and Andhra Pradesh, PCB 141 for Punjab, and HC 4 for Haryana (Table 4). Most of the hybrids were released for cultivation throughout India.

Of all the cultivars, WC-C75 was the most widely grown: in Zambia and in the Indian states of Maharashtra, Andhra Pradesh, Tamil Nadu, Madhya Pradesh, Karnataka, Haryana, and Rajasthan. Other widely-grown cultivars are ICMH 451, Pusa 23, and HHB 67. ICTP 8203 and MLBH 104, immensely popular, particularly in Maharashtra, once covered more area than any other cultivar in any single state. Seed production of several recently released or promising cultivars (e.g., ICMV 155 as a replacement for WC-C75, ICMV 221 as a replacement for ICTP 8203, and ICMH 356 and Pusa 322 as replacements for Pusa 23 and ICMH 451) has just started.

Seed supplies

Cultivar development at IAC has been backed by strong seed production programs, as reflected, in the extent of this activity during the last four recent years

Table 4. Features and adoption of released pearl millet varieties and hybrids developed by ICRISAT Asia Center (IAC) and/or Indian NARS using IAC plant material.

Variety/ hybrid	Features[1]	Location[2]	
		Recommended	Popular
Varieties			
WC-C75	High DMR, GY, FY	All India	MS, TN, AP, MP, KA, HA, RAJ
ICMS 7703	High DMR, GY, FY	All India	TN
ICMV 155	High DMR, GY, FY	All India	New release
RCB-IC 9	High GY, FY, DMR; uniform	All India	Seed not available
ICMV 221	High DMR, GY; short-duration; large seeds	> 400 mm rainfall	New release
ICTP 8203	High DMR, GY; short-duration; large seeds	MS, AP,	MS
PCB 141	High GY, DMR; large seeds	Punjab	New release
HC 4	High DMR, GY, FY	HA	Not adopted
Hybrids			
ICMH 451	High GY, FY; good DMR; bristled; good grain quality	All India	MS, AP, HA, RAJ, GUJ
ICMH 423	High GY, FY; DMR	All India	Not adopted
ICMH 501	High GY, DMR, large seeds	All India	Not adopted
ICMH 356	High GY; short-duration; large seeds	All India	New release
MLBH 104	High GY; short-duration; large seeds	All India	MS
Pusa 23	High GY, FY; DMR	All India	MS,AP, GUJ, HA
Pusa 322	High GY, FY; DMR	All India	New release
HHB 50	Good GY; short-duration; good tillering	HA	HA
HHB 60	Good GY; short-duration; good tillering	HA	HA
HHB 67	Good GY; very short-duration; good tillering	HA	HA, RAJ, GUJ
HHB 68	Good GY; very short-duration; good tillering	HA	New release
RHB 30	Good GY, DMR; short-duration; good tillering	RAJ	New release

1. DMR = downy mildew resistance, GY/FY = grain/fodder yield.
2. MS = Maharashtra, TN = Tamil Nadu, AP = Andhra Pradesh, MP = Madhya Pradesh, KA = Karnataka, HA = Haryana, RAJ = Rajasthan, GUJ = Gujarat.

(Table 5). Each year we supply roughly up to 1500 kg of breeders' seed, comprising up to 20 genotypes. Based on the standard seed multiplication ratio of 1:200 and pooling the production over two generations, this quantity is enough to produce certified seed required for the entire pearl millet area in India. However, some of the seed is sown directly, i.e., without raising another generation, to produce certified seed. Therefore, at times, the supply falls short of the requirements.

Table 5. Pearl millet seeds supplied worldwide from ICRISAT Asia Center, 1990-93.

Year	Breeder seed			Number of samples[1]		
	No. of samples	No. of entries	Quantity (kg)	Breeding lines	Trials and nurseries	Total
1990	441	16	1206	1956	1276(85)[2]	3332
1991	469	16	1282	2799	1945(107)	4744
1992	595	16	1476	5360	2724 (108)	8084
1993	706	21	1432	3142[3]	2330 (58)[3]	5472

1. Excludes samples from Genetic Resources Division, ICRISAT.
2. Numbers in parentheses indicate number of sets.
3. Jan-Sep only.

Besides the development of varieties/hybrids and parental lines, development of genetically enhanced germplasm for use in NARS breeding programs has been a major research activity at IAC. We supply seeds of breeding lines as well as seed samples for laying out field trials or for raising nurseries worldwide (Table 5). Supply of these materials, comprising mostly experimental varieties, segregating populations, and early/advanced generation progenies, has substantially diversified the genetic base of NARS breeding programs.

Cultivars for REIA workplan

Cultivars that can be taken up for research evaluation studies (both impact and constraint analyses) are listed in Table 6. Another cultivar—HHB 67, released in

Table 6. Peart millet cultivars identified for REIA workplan (impact and constraint analysis).

Objective	Cultivar	Location[1]
Impact analysis	WC-C75	TN, MS, ERAJ, GUJ, Zambia
	ICMH 451	MS, ERAJ, GUJ
	ICTP 8203	MS, Namibia (Okashana 1)
	Pusa 23	GUJ, ERAJ
	MLBH 104	MS
	RCB-IC 911	RAJ
Constraint analysis	ICMH 501	MS
	ICMS 7703	MS, HA, TN
	ICMH 423	MS, GUJ
	HC 4	HA
	RCB-IC 9	ERAJ

1. TN = Tamil Nadu, MS = Maharashtra, ERAJ = eastern Rajasthan, RAJ = Rajasthan, GUJ = Gujarat, HA = Haryana.

1990—could also be considered subsequently. Although sown over a relatively small area at present, HHB 67 is the earliest-maturing cultivar so far released in India. It is popular in the drier areas of Haryana, Rajasthan, and Gujarat, and it would be useful to track its spread and subsequent performance.

In the case of RCB-IC 911, a short-duration, drought-tolerant, downy mildew resistant variety, REIA studies should include the methodology of collaborative varietal development, farmers' participation in pre-release evaluation, and seed production. RBC-IC 911, expected to be released in 1994, was developed jointly by IAC and the Rajasthan Agricultural University, and evaluated concurrently in A1CPM1P trials and in on-farm trials in 1991-93 in Ajmer district, Rajasthan. Farmers' participation, particularly in the assessment of varietal characteristics, was a major feature of this project. Seed multiplication has already begun at IAC and in the villlages where on-farm trials were conducted. Seed availability will, therefore, not be a constraint to its adoption in the first two years after its release.

Genetic Improvement of Chickpea

S C Sethi and H A van Rheenen[1]

Introduction

The major biotic constraints limiting chickpea production are wilt and root rots, ascochyta blight, botrytis gray mold, and stunt virus among diseases; and pod borer (*Helicoverpa armigera)* and leaf miner (*Liriomyza cicerina*) among insect pests. The abiotic stresses responsible for low yields are drought, cold, and heat, and in some regions salinity and acidity. ICRISAT has addressed these specific problems while developing breeding materials adapted to different agroecological zones. The scope for extending the adaptation of *chickpea* to new cropping systems in each of these *adaptation* zones has also *received* our attention (Table 1).

Future research objectives

The future objectives of ICRISAT's chickpea program are to develop desi and kabuli varieties for different production systems in collaboration with NARS, following the polygon breeding approach. This approach entails an equal partnership among the collaborators, allowing researchers to identify varieties for local and/or wide adaptation. Such production systems have been identified for chickpea in Asia, eastern Africa, and Latin America. The research focus for each system is determined by the

Table 1. Past objectives of ICRISAT's chickpea improvement program.

Latitude	Maturity/ duration	Seed type	Stress: Biotic	Stress: Abiotic	Extended adaptation
0-20°	Extra-short and short	D, K	W+RR, Hel	DR, Heat	Early sowing
20-25°	Medium	D, K	W+RR, Hel	DR	Rice-based
25-30°	Long	D, K	W+RR, AB, BGM, STN, Hel	Cold, DR	LS, HI
>30°	IC/ICARDA	K(D)	AB, LM	Cold, DR	Winter sowing

D = desi, K = kabuli, W+RR = wilt and root rots, Hel = *Helicoverpa*, DR = drought, LM = leaf miner, AB = ascochyta blight, BCM = botrytis gray mold, STN = stunt virus, LS = late sowing, HI = high input.

1. Genetic Enhancement Division, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.

major constraints in that system. Broadly, ICRISAT's priority research areas are as follows:

- Asia—drought, ascochyta blight, *Helicoverpa,* wilt, root rot, biological nitrogen fixation, suboptimal yield, stunt, cold tolerance, and botrytis gray mold.
- Eastern Africa—drought, *Helicoverpa,* wilt and root rots, biological nitrogen fixation, suboptimal yield, and stunt.
- Latin America—drought, *Helicoverpa,* wilt and root rots, biological nitrogen fixation, suboptimal yield, and stunt.

We will continue to supply seed of our varieties to cooperators, seed companies (both public and private sector), and farmers as in the past. Various methodologies, as they are developed, will be freely shared with NARS in different countries through literature, visits by scientists, and training.

Released cultivars

ICRISAT has developed nine varieties of chickpea—ICCVs 1, 2, 3, 5, 6, 10, and 88202, ICCC 37 and ICCC 42—that have become popular in India; in particular, ICCV 2, ICCV 88202, and ICCC 37 in Andhra Pradesh, Maharashtra, and Gujarat. NARS in other countries have also released varieties from ICRISAT-supplied breeding material (Table 2). These include Sita, Kalika, and Kosheli in Nepal; Nabin, Barichhola 2, and Barichhola 3 in Bangladesh; and Schwe Kyemon in Myanmar. Some of these varieties (Kalika and Kosheli in Nepal, Nabin in Bangladesh) are replacing traditional varieties.

NARS collaboration

Between 1980 and 1993, 52 varieties have been released in India (Table 3), of which 11 originated from ICRISAT material. ICRISAT's contribution can also be gauged from the fact in the previous 10 years, on an average 12% of the entries in the AICPIP trials were selections from ICRISAT-supplied material.

To our chickpea cooperators worldwide, we have been supplying both breeding material and finished products (varieties) to enable them to identify genotypes best suited to specific regions or cropping systems. ICRISAT has also developed technologies that are widely used by NARS. For example, screening methodologies developed for wilt and root rots, stunt, and ascochyta blight have become standard methods to develop disease-resistant genotypes. Collaborative disease nurseries have jointly been organized by contributions from ICRISAT, AICPIP in India, and NARS in other countries. Similarly, our physiologists organize collaborative drought and cold nurseries, and coordinate the publication of 'News and Views', an informal medium for communications relating to the Global Grain Legumes Drought Research Network (GGLDRN). Entomologists from ICRISAT and AICPIP jointly run *Helicoverpa* screening nurseries, where resistant lines have been identified. These collaborative activities

Table 2. Popular chickpea varieties in India and elsewhere, bred from ICRISAT-supplied material.

Variety	Pedigree	Starting year	Product identified	Product released
India				
ICCV 1	H208 × T3	1973	1982	1983
ICCV 2	F_3(K850 × GW5/7)P458 × F_3(L550 × Guamuchil)	1975	1984	1989
ICCV 3	F_3[(K850 × GW5/7)P458] × F_3(L550 × Guamuchil)	1975	1984	
ICCV 5	CPS-1 × C104	1978	1984	
ICCV 6	L550 × L2	1984	1985	
ICCV 10	P1231 × P1265	1975	1992	1993
ICCV 88202	PRR-1 × ICCC 1	1977	1988	
ICCC 37	P481 × (JG62 × P1630)	1974	1989	1989
ICCC 42	(K850 × GW5/7) × (H208 × Annigeri)	1974	1984	–
Nepal				
ICCV 1 (Sita)	H208 × T3	1973	–	1987
ICCL 82108 (Kalika)	F_2(JG62 × WR315)-2 × F_2(P1363 × PRR-1)-2	1976	–	1990
ICCV 6 (Kosheli)	L550 × L2	1973	–	1990
Bangladesh				
ICCL 81248 (Nabin)	P 481 × (JG 62 × P1630)	1974	–	1986
ICCL 83228 (Barichhola 2)	P 1231 × P.1265	1975	–	1993
ICCL 83105 (Barichhola 3)	F_2 (K850 × T3) × (JG 62 × BEG 482)	1974	–	1993
Myanmar				
ICCV 2	F_3 [(K850 × GW5/7) × P458] × [F_3(L-550 × Guamuchil)]	1975	–	
Schwe Kyemon	Sel. from K 850 × F378	1974	–	
Ethiopia				
Mariye	Sel. from K 850 3/27 × F378	1974	–	1988
Kenya				
ICCL 83110	F_2(K850 × T3) × F_2 (JG 62 × BEG-482)	1974	–	1986

Table 3. Chickpea varieties released in India since 1980.

Variety	Year	Type[1]	State[2]	Pedigree	Remarks
Pusa 209	1980	D	IARI	P827 × SchwC235	
GL 769	1981	D	PU	H223 × L168	Wide adaptation
JG 221	1981	D	MP	Sel from germplasm	Tolerant of root disease
JG 5	1981	D	MP	Selection from G.P.	Local adaptation
K 468	1982	D	UP		Pink-seeded
Redley	1982	D	UP	197 × 76	Wide adaptation
Pant G 114	1982	D	UP	G 130 × 154	Local adaptation
Pant G 115	1982	D	UP		Double-podded, wide adaptation
B 108	1982	D	WB		Local adaptation
B 115	1982	D	WB	N31 × B 75	Wide adaptation
B 124	1982	D	WB	N31 × B 75	
CO2	1982	D	TN		Short-duration
Pusa 212	1982	D	IARI	P3409 × G130	Short-duration
BDN 9-3	1982	D	MS	Local selection	Tolerant of wilt
Avrodhi	1982	D	UP	T2 × K 315	Short-duration, wide adaptation
Mahamaya	1982	D	WB		Wide adaptation
Vikas	1983	D	MS	Khanpur 6 × AF 7-10	Wide adaptation
Gaurav	1983	D	HA	C235 × E100Y	Ascochyta resistant
ICCC 4 (ICCV 1)[3]	1983	D	IAC	H208 × T3	Wide adaptation
Pusa 256[4]	1984, 88	D	IARI	(JG 62 × K850) × L550 × H208)	Wide adaptation, bold-seeded
RSG 44[4]	1984	D	RAJ	JG 62 × F496	Wide adaptation
Anupam[4]	1984	D	UP	F378 × F404	Wide adaptation
GNG 149[4]	1985	K	RAJ	L550 × L2	Wide adaptation
ICCC 32 (ICCV 6)[3]	1985	K	IAC	L550 × L2	Wilt resistant
BG 244[4]	1985	D	IARI	(K850 × P922) × P9847	Wide adaptation
Pusa 408	1985	D	IARI	Mutant of G 130	Wide adaptation
BGM 413	1985	D	IARI	Mutant of G 130	Wide adaptation
BGM 417	1985	D	IARI	Mutant of BG 203	Wide adaptation

Continued ....

Pigeonpea Germplasm Management and Enhancement

R P Ariyanayagam and K C Jain[1]

Introduction

Several biotic and abiotic factors severely constrain the productivity of pigeonpea. Drought is a major abiotic constraint, and occurs unpredictably at different plant growth stages. The newer short-duration pigeonpea cultivars which escape terminal drought encounter waterlogging stress, which can cause severe loss of yield in black soils. Pest-inflicted losses are by far the major yield-limiting factor, and management of pests appears to be the best option. In contrast, losses caused by diseases have been effectively controlled through host-plant resistance breeding.

The varieties and hybrids developed in recent years escape drought, and have been bred for effective genetic protection against the major diseases. Pest damage in these varieties/hybrids can be managed, but they still lack genetic protection against several major constraints.

Research objectives

Impact assessment of pigeonpea germplasm enhancement and management activities is viewed in the context of past objectives and achievements, and projections for the future in terms of future objectives. Germplasm enhancement objectives in the past were heavily weighted in favor of constraint alleviation. These objectives were to:

- Develop, evaluate, and identify new hybrids (mainly short-duration, some medium- and long-duration);
- Develop efficient seed production technology for hybrids and male steriles;
- Search for new sources of male sterility and transfer male-sterility gene(s) to elite genotypes and new plant types;
- Transfer seed production technology to seed companies and NARS through seed supply and training.

The germplasm enhancement objectives for the future, which include the gradual introduction of cytoplasmic male-sterility, can be described by the research themes identified in the Institute's medium term plan (Table 1). The themes, as in the past, are targeted mainly at the major biotic and abiotic constraints. The improvement of yield potential is considered the most important objective, as NARS in most pigeonpea-producing countries have requested higher-yielding finished products or populations.

1. Genetic Enhancement Division, ICRISAT, ICRISAT Asia Center, Patancheru, Andhra Pradesh 502 324, India.

Table 1. Themes for future pigeonpea research at ICRISAT.

Research theme	Center(s)
Genetic yield potential	IAC/EARCAL[1]
Sterility mosaic/fusarium wilt	IAC
Helicoverpa management	IAC
Nematodes	IAC
Drought	IAC/EARCAL
Phytophthora blight management	IAC
Helicoverpa resistance	IAC
Maruca	IAC
Podfly management	IAC/EARCAL
Waterlogging	IAC
Podfly resistance	IAC/EARCAL

1. IAC = ICRISAT Asia Center, EARCAL = Eastern Africa Regional Cereals and Legumes Program.

Deviating from the earlier approach, breeding research in the future will be targeted at specific production systems, such as the 12 production systems identified in Asia. For instance, drought is the single major constraint in production system 1 (arid and semi-arid transition rangeland and rainfed zone; includes western Rajasthan, northern Gujarat, and eastern Pakistan). In contrast, production system 7 (tropical intermediate eastern Deccan plateau; includes Maharashtra, northwestern Andhra Pradesh, northeastern Karnataka, and southern Madhya Pradesh) is far more 'difficult'. It is severely affected by several factors: low yield potential, wilt, sterility mosaic, *Helicoverpa*, drought, and several other constraints. An integrated research effort will be made in this difficult production system to alleviate the constraints, and thereby increase production and minimize crop damage (complete alleviation is not a realistic expectation).

Released cultivars

Several varieties and hybrids have been developed by ICRISAT, and are being used by farmers in India and other countries (Table 2). Adoption rates have been satisfactory, because of improved yield, drought escape through earlier maturity, and incorporation of resistance to diseases. However, the expansion of cultivated area has been erratic for some varieties in some regions. For instance, ICPL 87 failed to take hold in the areas where its cultivation was advocated, but is spreading in other parts of India (parts of Maharashtra, Gujarat, and Tamil Nadu) and in Sri Lanka. In Myanmar it is reported to be spreading rapidly. Similarly, ICP 8863 in India and ICP 9145 in Malawi also have good adoption rates.

Table 2. Pigeonpea varieties/hybrids developed at ICRISAT.				
ICRISAT name/ identity	Other name	Release name	Year of release	Characteristics/features
India				
ICPV 1	ICP 8863	Maruti	1985	Medium-duration, wilt-resistant, for Karnataka
ICPL 87	T 2 1 x ICP 6993	Pragati	1986	Short-duration, high-yielding wide adaptation, suitable for multiple harvesting
ICPL 151	ICP 6997 x Prabhat	Jagriti	1989	Short-duration, suitable for double cropping with wheat in northern India
ICPL 332	Sel. from ICP 1903	Abhaya	1989	Medium-duration, pod borer tolerant
ICPH 8	ms Prabhat DT x ICPL 161	ICPH 8	1991	Short-duration high-yielding hybrid, wide adaptation
ICPX 78120-WB-WB-WB		Birsa Arhar 1	1992	Wilt-resistant bulk population for Bihar
ICPL 87119	C 11 x ICP 1-6	Asha	1993	Medium-duration wilt and sterility mosaic resistant variety for Central and Southern Zones
IPH 732	ms T-21 x ICPL 87109	In pre-release stage in Tamil Nadu		Short-duration, indeterminate high yielding hybrid
ICPL 87051	ICP 7979 xC11			Medium-duration, wilt and sterility mosaic resistant, white, bold-seeded
Australia				
Prabhat x Baigani	QPL 1	Hunt	1983	Extra short duration, high-yielding
T 21 x JA 277	QPL 42	Quantum	1985	Short-duration, high-yielding
Sel. from (Prabhat x HY 3C) x (ICP 7018 x ICP 7035)		Quest	1988	Short-duration, high-yielding
Fiji				
ICP 7035		Kamica	1985	Medium-duration, wilt and sterility mosaic resistant, large-seeded
Indonesia				
Prabhat x Baigani	Hunt	Megha	1987	Short-duration, high-yielding
Malawi				
ICP 9145		Nandolo Wanswara	1988	High-yielding, wilt-resistant, large-seeded

Continued....

Table 2. *Continued.....*				
ICRISAT name/ identity	Other name	Release name	Year of release	Characteristics/features
Myanmar				
ICPL 87		ICPL 87	1990	Short-duration, high-yielding, wide adaptation
Nepal				
ICP 11384		Bageshwari	1992	Long-duration, high-yielding, sterility mosaic resistant
ICP 6997		Rampur Rhar 1	1992	Medium-duration, sterility mosaic resistant

NARS collaboration

Research collaboration with national programs in various countries is a major aspect of ICRISAT's work on pigeonpea. The Institute initiated a hybrid pigeonpea cooperative program involving 10 research centers in India. As a result of collaborative research under this program, several hybrid combinations were made, and male sterility transferred into 27 backgrounds of well-adapted, improved, resistant varieties.

NARS have developed varieties and hybrids adapted to their respective regions and production systems using genetic materials supplied by ICRISAT. These are listed in Tables 3 and 4. ICRISAT parental lines are extensively used in NARS breeding programs; in particular, the entire hybrid breeding program in India is based on genetic male-sterile lines supplied by ICRISAT. Some NARS have converted these into male-sterile source lines adapted to their environments (Table 5). For example, ms CO 5 contains the ms gene supplied by ICRISAT. This is an instance where the Institute's contribution to NARS research may not be readily visible. In these and many other

Table 3. Pigeonpea varieties developed by NARS from ICRISAT material.

Variety	Feature	Locations where released
Birsa Arhar 1	Wilt-resistant	Bihar
Bageshwari	SM-tolerant[1]	Nepal
Rampur Rhar 1	SM-tolerant	Nepal
ICPL 295 (Brooks and Saluder)	Wilt-resistant	Philippines
ICPL 87091	Vegetable pigeonpea	Gujarat, southern Africa, Latin America

1. SM = sterility mosaic disease

Table 4. Pigeonpea hybrids developed by NARS from ICRISAT plant material.

Hybrid	ICRISAT parental material	Bred at	Features of parental material
CPH 953	ms CO5 x ICPL 87109	Coimbatore	Male parent short-duration, determinate, with large white seeds and good combining ability
KE 1	ms Prabhat x T.21	CSAU	Female parent determinate, short-duration, with good combining ability

Table 5. Male-sterile pigeonpea parents developed at ICRISAT for use by NARS.

Center[1]	Male-sterile line
DPR, Kanpur	ms 3783, ms Prabhat NDT, IMS 1
IARI, New Delhi	ms Prabhat DT, ms Prabhat NDT, IMS I, QMS 1
PAU, Ludhiana	ms Prabhat DT, QMS 1, IMS 1
HAU, Hisar	ms Prabhat DT, ms Prabhat NDT, QMS 1, IMS 1, ms T. 21
GAU, SK Nagar	ms 3783, ms Prabhat DT, ms ICPL 87091, ms T.21, IMS 1, QMS 1, ms C 11
TNAU, Coimbatore	QMS 1, QMS 9, ms Prabhat, IMS 1, ms T.21
PKV, Akola	QMS 1, QMS 9, ms Prabhat DT, IMS 1
RAU, Dholi	ms 3783, ms Prabhat NDT, ms Prabhat DT, ms T.21
NDUAT, Faizabad	ms 3783

1. DPR = Directorate of Pulses Research, IARI = Indian Agricultural Research Institute, PAU, HAU. GAU, TNAU, RAU = Punjab, Haryana, Gujarat, Tamil Nadu, Rajendra Agricultural University, PKV = Punjabrao Krishi Vidyapeeth, NDUAT = Narendra Dev University of Agriculture and Technology.

cases, the impact of ICRISAT research is felt—and must be quantified—in terms of genetic contributions or intermediate outputs. Table 6 lists some pest- and disease-resistant lines developed by ICRISAT, which have been recommended by the All India Coordinated Pulses Improvement Project (AICPIP).

An interesting example of a segregating population being the source of a selection acceptable to farmers comes from Bihar. The population was developed for wilt resistance at ICRISAT Asia Center, and made available on request to a research center in Bihar in 1982. Ten years later a selection from this population named Birsa Arhar 1 was released in Bihar, and is reportedly performing well.

Table 6. Pest- and disease-resistant pigeonpea lines developed by ICRISAT, and recommended by AICPIP[1].

Center	Disease/Pest	Pigenopea line/accession
Dholi	SM[2]	ICP 7035, ICP 8862, ICP 10976
Rahuri	Fusarium wilt	ICPL 89044, ICP 8094, ICPL 86005, ICPL 88023, ICPL 88025
Rahuri	Wilt, SM	ICPL 88046, ICPL 88047, ICPL 87119, ICPL 87104
Lam	SM	ICPL 87119
	Helicoverpa	ICPL 332
	Wilt	ICP 8859
	Wilt, SM	ICPL 87119, ICP 8860
National	Wilt	ICP 8869
crossing program	Wilt, SM	ICPL 83027, ICPL 83024, ICPL 87119, ICPL 85047, ICP 8860

1. AICPIP = All India Coordinated Pulses Improvement Project. 2. SM = sterility mosaic.

REIA workplan

Six varieties/hybrids are suggested for impact analysis: ICPLs 87, 151, 85012, and 87119, ICPH 8, and ICP 8863 (released as Maruthi in Karnataka). In addition the impact of ICRISAT-supplied parental lines could be evaluated. One hybrid and three varieties are suggested for constraint analysis: ICPH 8 and ICPLs 87, 151, and 332.

Germplasm Enhancement in Groundnut

L J Reddy and S N Nigam[1]

Introduction

Groundnut is a major oilseed and food crop worldwide; 23 million t were produced from 20 million ha in 1992. Groundnut production systems, though diverse, can be broadly classified into four groups.

- Rainfed areas, where short- and medium-duration cultivars are grown for oil, food, and fodder;
- Areas with supplemental irrigation, where mostly medium-duration cultivars are grown for oil and confectionery use;
- High-input systems, in which medium- and long-duration cultivars are grown for oil and confectionery use;
- Residual-moisture systems, in which short-duration cultivars can be grown for oil and food.

Production constraints. Several biotic and abiotic stresses limit groundnut production to varying extents in different regions. The important biotic stresses include early and late leaf spots and rust among foliar fungal diseases; peanut bud necrosis virus, peanut stripe virus, rosette, and peanut mottle virus among virus diseases; and jassids, thrips, termites, leaf miner, *Spodoptera,* and white grubs among insect pests. Rosette is restricted to the African continent and surrounding islands. Bacterial wilt is widespread in East and Southeast Asia. The abiotic stresses include drought, iron chlorosis, soil acidity, low soil fertility, and low temperatures. These constraints often occur in combinations.

Research Objectives

Past/current objectives. Groundnut breeding research at ICRISAT has been conducted with the following objectives: high yield potential and wide adaptation, development of confectionery varieties, resistances to foliar diseases, *Aspergillus flavus,* viruses, and insect pests, and drought tolerance. Most of these objectives continue to receive our attention. Significant progress has been made in several areas, e.g., increasing yield potential and resistance to thrips and jassids. In these cases there has been a corresponding decrease in further research inputs, efforts being directed at other problems.

---

1. Genetic Enhancement Division, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.

Future objectives. Improved high-yielding groundnut varieties have been released in India and several other countries. The recent releases in India have resulted in a genetic pod yield gain of 1.3-3.2% per year. These productivity gains need to be sustained by incorporating resistance/tolerance to the prevailing biotic and abiotic stresses. To increase production further, cultivars suited to specific production systems are required. To sustain groundnut production, diversified products and uses must be developed; work on value-added products and specific traits relating to consumer acceptability will therefore need to be intensified. Future breeding objectives should thus include biotic and abiotic stress alleviation, specific adaptation, and improvement of specific characters required for various end uses.

Germplasm enhancement at ICRISAT

Groundnut breeding research at ICRISAT began in 1976 at ICRISAT Asia Center. From 1979 till date (where records are available) we have made 7920 crosses for different breeding objectives, using 532 germplasm lines, 718 advanced breeding lines, and 161 interspecific derivatives. We have also successfully exploited natural hybrids to develop high-yielding cultivars.

Over the years, the breeding research focus at ICRISAT has shifted from finished products to the development of genetically enhanced, advanced breeding lines/populations, from which our national collaborators select material best suited to local conditions. Breeding materials developed at ICRISAT—elite germplasm, segregating populations, and advanced breeding lines—are supplied to national programs on request, as are international varietal trials.

Table 1. ICRISAT-developed groundnut cultivars released in India.

Variety	Pedigree	Research initiated	Product identified	Product released
ICGS 11 (ICGV 87123)	Natural hybrid derivative from Kadiri 3	1977	1980/81	1986
ICGS 44 (ICGV 87128)	-do-	1977	1982/83	1988
ICGS 76 (ICGV 87141)	TMV 10 x Chico	1977/78	1985	1989
ICGS 37 (ICGV 87187)	Natural hybrid derivative from Kadiri 3	1977/78	1980/81	1990
ICGS 1 (ICGV 87119)	-do-	1977/78	1981	1990
ICG (FDRS) 10 (ICGV 87160)	Ah 65 x NC Ac 17090	1978	1983	1990
ICGV 86590	X 14-4-B-19-B x PI 259747	1979	1988	1991
ICGV 86325	ICGS 20 x G 201	1980	1989	1994

Released cultivars

Tables 1 and 2 list groundnut cultivars developed by ICRISAT and released through the national programs in India and elsewhere. Among the Indian releases for postrainy season cultivation, ICGS 11 and ICGS 44 are suitable for Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra, and Madhya Pradesh and ICGS 37 for Gujarat. ICGS 76, ICG (FDRS) 10, and ICGV 86590 are suitable for rainy-season cultivation in peninsular India; the last two are resistant to rust and tolerant of late leaf spot, both of which can cause substantial yield losses in that region. ICGS 1 is suitable for both spring and rainy-season cultivation in northern India.

Table 2. ICRISAT-developed groundnut varieties released outside India.

Country	Variety	ICRISAT parent material	Year of release
South Korea	Jinpungtongkong	ICGS 35	1987
Pakistan	BARD 699	ICGS 44 + ICGS 37	1989
Ghana	Sinkarzei	ICGS 114	1989
Malawi	CG 7	ICGMS 42	1990
Zambia	MGV 4	ICGMS 42	1990
Republic of Guinea	VP 20	ICGV 86105	1992/93
Myanmar	Yezin 5	ICGV 87160	1993

NARS collaboration

The impact of ICRISAT's groundnut research can also be measured in terms of collaborative studies with NARS. Our cooperators in Asia and Africa have released a number of cultivars developed from advanced breeding lines, segregating populations, and germplasm accessions supplied by ICRISAT (Table 3). From the segregating materials, VRI 1, a short-duration variety with fresh seed dormancy and high shelling percentage; ALR 1 (a rust-resistant variety); and Girnar 1 (with multiple disease resistance) have been developed in India. Similarly, from ICRISAT's advanced breeding lines, Spring Groundnut '84 in Punjab, Konkan Gaurav in Maharashtra, and RG 141 in Rajasthan have been developed. ICRISAT-supplied germplasm accessions that have ben released as cultivars include Sinpadetha 2 and 3 in Myanmar, Johari in Tanzania, Cardi-Payne in Jamaica, ICG 7794 in Ethiopia, BARD 479 in Pakistan, and UPL Pn 10 in the Philippines.

A number of lines are in the testing and pre-release stages in various countries. In India, one short-duration variety (ICBS 86143), two confectionery varieties (ICHNG

Table 3. Groundnut varieties developed by NARS using ICRISAT parent material and released in India.

Variety	ICRISAT parent material	Bred/ selected by[1]	Year of release	Features of parent material
Spring Groundnut '84	ICGS 1	PAU, Punjab	1984	Matures in 112 days; tolerant of bud necrosis disease; high shelling percentage; good oil quality
Konkan Gaurav	ICGS 1	KKV, Maharashtra	1990	Matures in 112 days; tolerant of bud necrosis disease; high shelling percentage; good oil quality
VRI 1	TMV 7 x FSB 7-2	TNAU, Vriddhachalam	1986	High shelling percentage; fresh seed dormancy
ALR 1	FESR selection	TNAU, Aliyarnagar	1987	Resistant to rust and late leaf spot
Girnar 1	X14-4-B-19-B x NC Ac 17090	NRCG, Junagadh	1989	Short-duration, multiple resistance to foliar diseases, aflatoxin, jassids, and drought
RG 141	Kadiri 3 x NC Ac 2821	RAU, Rajasthan	1989	High-yielding

1. PAU, RAU, TNAU = Punjab, Rajasthan, Tamil Nadu Agricultural University, KKV = Konkan Krishi Vidyapeeth, NRCG = National Research Centre for Groundnut.

88438 and ICHNG 88398), and a drought-tolerant variety (ICDRG 87354) are in various stages of testing (Table 4). Similarly, several ICRISAT-bred varieties are in advanced stages of testing in other countries. These include ICGS(E) 56 in Pakistan and Bangladesh, ICGS(E) 52 in Gambia, ICGS(E) 11 in Bangladesh, ICGS 11 in

Table 4. Groundnut varieties developed jointly by ICRISAT and NARS, currently in testing and pre-release stages.

ICGV no.	AICORPO[1] no.	Year	Trial	Proposed by
ICGV 86143	ICBS 86143	1992/93	IVT	Bhavanisagar, Tamil Nadu
ICGV 88438	ICHNG 88438	1993/94	HPSVT	Hanumangarh, Rajasthan
ICGV 88398	ICHNG 88398	1993/94	HPSVT	Hanumangarh, Rajasthan
ICGV 87354	ICDRG 87354	1993/94	NDRVT	Durgapur, Rajasthan

1. AICORPO = All India Coordinated Research Project on Oilseeds.

Benin, ICGV 86553 in Cyprus, ICGV 87157 in Sierra Leone, and ICGV 87350 in the Philippines. In addition to these cultivars, several elite germplasm lines have also been developed for use by national programs as sources of resistance to multiple diseases and insect pests (Table 5).

Table 5. Elite groundnut germplasm developed at ICRISAT Asia Center.

Genotype	Attributes
ICGV 87157 [ICGV (FDRS) 4]	Resistant to rust, tolerant of late leaf spot, moderately resistant to bud necrosis disease
ICGV 86031	Multiple resistance/tolerance to *Spodoptera,* leaf miner, jassids, thrips
ICGV 86699	Multiple resistance/tolerance to rust, late leaf spot, bud necrosis, stem and pod rots, *Spodoptera,* jassids
ICGV 86564	Dual-purpose elite line suitable for direct consumption as seed and for oil

REIA workplan

The following varieties are suggested for impact analysis:

India

- ICGS 44 (Andhra Pradesh, Tamil Nadu)
- ICGS 11 (Maharashtra, Andhra Pradesh)
- ICGS 76 (Maharashtra)
- ICGS 21 (Maharashtra)
- ICGV 86590 (Andhra Pradesh, Karnataka, Tamil Nadu)

Other countries

- BARD 699 (Pakistan)
- ICGMS 42 (Zambia, Malawi)

For constraint analysis the following varieties are suggested:

- ICG (FDRS) 10 (Andhra Pradesh, Maharashtra, Karnataka, Tamil Nadu)
- ICGS 37 (Gujarat)
- ICGV 86564 (high-management areas in Maharashtra, Andhra Pradesh)

Although some of the above varieties have been released in India, they have not become popular. The reasons are not clear, but it appears that in some cases, e.g., ICG (FDRS) 10, the pods are not attractive and therefore not acceptable to farmers.

Crop and Resource Management Research

Soil, Water, and Nutrient Management

T J Rego[1]

Introduction

Improved management of natural resources such as soil and water, in conjunction with crop improvement, will result in higher productivity in all farm lands. The efficient use of natural resources is a prerequisite to the development of improved farming systems that will help increase and stabilize agricultural production in the seasonally dry semi-arid tropics (SAT). Because of population pressures, even marginal lands are now cultivated and natural recuperation systems discarded. For example, lands are not kept fallow at all; if they are, it is for periods too short to be effective. Continuous crop production with minimal external inputs in these soils has further depleted soil nutrients, and reduced crop productivity. Poor crop coverage and improper rainfall water management have led to soil erosion and ultimately to degraded soils.

Objectives

At ICRISAT, the main objectives of soil and water management in the past were to:

- Improve the efficiency of rainwater use;
- Conserve the soil;
- Improve soil fertility.

The efficiency of rainwater use was improved in three ways: *in situ* conservation of rainwater (by increasing infiltration), water harvesting, and improvement in drainage. Soil conservation involved reductions in runoff and erosion. Soil fertility was improved by integrated nutrient management, which involved:

- Improving fertilizer-use efficiency;
- Use of legumes in cropping systems as sources of nitrogen;
- Use of farmyard manure (FYM);
- Use of crop residues.

Future objectives include, in addition to the three objectives mentioned above, two others:

- Conservation of resources, i.e., prevention of degradation;
- Amelioration, i.e., improvement of resources, restoring them to their original levels if possible.

1. Soils and Agroclimatology Division, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.

Research studies

The emphasis on nutrient management was mainly on N, followed by P and to some extent, K. Optimum quantities of fertilizers, and time and method of application, were worked out for various cropping systems on Vertisols and Alfisols. Studies on the role of grain legumes as nitrogen-providing rotation crops gave us very useful information. The role of FYM in SAT crop production was studied through village surveys.

Watershed technology

The watershed concept is a holistic approach to efficient soil and water management. ICRISAT oriented its work on a 'watershed basis', assembling various components of soil and water management into technologies suitable for SAT Vertisols and Alfisols.

Vertisol watershed technology consists of:

- Summer plowing;
- Improving drainage by land shaping, land smoothening, broad bed and furrows (BBF), and grass waterways;
- Early canopy cover;
- Double cropping.

In traditional cropping systems land is kept fallow in the rainy-season and cropped in the postrainy season. Instead, ICRISAT recommended dry-seeding the rainy-season crop, thus cropping in both seasons, either by intercropping with long-duration crops or by sequential cropping.

Alfisol watershed technology consists of:

- Contourcultivation;
- Use of vegetative barriers;
- Proper tillage.

ICRISAT scientists have developed a wheeled tool carrier and T-bar implements drawn by bullocks to carry out most field operations quickly and efficiently.

Though the watershed approach is an excellent way to manage soil and water, some components (e.g., land development) require substantial capital input and yield benefits only in the long term. Without government help these components are beyond the reach of poor farmers. However, they can use other components such as integrated nutrient management (e.g., legume-based cropping systems enhanced with small quantities of fertilizer); use of broad bed and furrows in Vertisols in medium-rainfall situations; and contour cultivation and vegetative barriers in Alfisols. A comprehensive review of watershed technology and associated constraints, and the impact (or the lack of it) of its various components, will help us to modify this technology if required, and extend its use to all relevant SAT soils.

Table 1. Outputs of ICRISAT research on soil, water, and nutrient management

Output	Component	Year when research started	Year when recommendation was made
1. Watershed concept for efficient management of soil and water resources	Climate (rainfall) Topography (slope) Soil Cropping systems Socioeconomics	1974	1980
Vertisols			
Timing of tillage (summer plowing) Improved drainage - land shaping, land smoothening, BBF[1], grass waterways easy canopy cover - Double cropping			
Alfisols			
Contour cultivation Vegetative barriers Tillage			
2. Use of wheeled tool carriers	Land preparation Seed and fertilizer placement Inter-row cultivation	1978	1983
Use of T-bar implements for groundnut production	Making of BBF Sowing Inter-row cultivation	1986	1988
3. Fertilizer management in cropping systems	Quantity of N, P, and K fertilizers Time of application Method of application	1976	1986
Use of grain legumes in cropping systems	Residual effect on succeeding nonlegume Long-term effects	1983	continuing
Use of FYM in crop production	Village surveys Use efficiency	1989	

1. Broad bed and furrow.

Impact assessment and constraint analysis

Some important outputs from ICRISAT research are listed in Table 1. The following technologies are recommended for impact/constraint analysis:

Impact assessment

- BBF technology for Vertisols.

Constraint analysis

- Water harvesting;
- Use of the Tropicultor;
- Adoption of T-bar implements for groundnut.

Other technologies which could also be considered for the REIA workplan are:

- Scoops;
- Vegetative barriers;
- Water harvesting;
- Use of grain legumes in integrated nutrient management.

Products of Plant Protection Research at ICRISAT

K F Nwanze[1]

Introduction

Plant protection research at ICRISAT is targeted at the reduction of crop losses due to a range of biotic stresses. Such stresses, which are a major constraint to sustainable farm productivity, are caused by a wide range of organisms—insect pests, nematodes, fungi, bacteria, viruses, and weeds. The research disciplines traditionally associated with plant protection work are entomology, pathology, virology, nematology, and weed science. However, plant protection research involves interdisciplinary collaboration amongst a still wider group of disciplines. For example, the development of pest-resistant genotypes would be unlikely to succeed without considerable input from breeding research. Similarly, the roles of agronomists and socioeconomists are pivotal in the development and implementation of integrated pest and disease management (IPM/IDM) strategies. Other disciplines are microclimatology, crop modeling, and cell and molecular biology. This paper focuses on insect pests and fungal and bacterial diseases that affect ICRISAT's mandate crops. It summarizes various products of research (such as cultivars, methodologies, and techniques) that have potential impact on NARS capabilities and farm productivity. Where appropriate, associated constraints are indicated as an aid to the identification of candidates for research evaluation and impact assessment (REIA).

Objectives

The identification and quantification of crop damage and yield loss is a basic prerequisite to defining research priorities, and subsequently meeting goals in a crop protection research agenda. At ICRISAT, studies have been conducted on applied insect and disease ecology and epidemiology of target organisms, identification of resistance sources and development of improved resistant cultivars, IPM/IDM components and their implementation, and insecticide resistance management. Technology exchange has traditionally been an important aspect of our work. These studies have generated new and improved technologies, but the delivery system has been less satisfactory. This necessitates a shift in future objectives to on-farm adaptive research in collaboration with NARS and farmers, implementation of IPM/IDM strategies, strategic research in defined areas, modeling, biotechnology, and nonconventional control methods. The identification of constraints to technology transfer should be addressed by the REIA team.

1. Crop Protection Division, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.

Optimization of plant defence mechanisms

In economic and practical terms, plant resistance is the cheapest, safest, and ecologically and sociologically most acceptable method of protecting crops against insect pests and diseases. In order to optimize this natural attribute (which is often lost in the process of cultivation and selection), pest populations or disease epidemics need to be manipulated to provide adequate levels of insect/disease pressure; this will improve the chances of successfully identifying resistant genotypes. Our outputs in this area include reliable and repeatable mass-rearing procedures for sorghum and pearl millet pests (stem and pod borers, defoliators, shoot pests, and panicle caterpillars) which are widely used by NARS institutions in Asia and Africa. Associated with these are screening techniques and standardized evaluation parameters for a range of insect pests and diseases (Table 1).

There has also been extensive documentation on resistance mechanisms and factors. Some of this work will form the basis of future research in gene mapping and marker-aided approaches in resistance breeding programs. Examples include root exudates in chickpea and pigeonpea resistance to wilt; trichome structure in groundnut resistance to jassids; chlorogenic acid (glycosides) in wild *Arachis* spp against

Table 1. Some resistance screening techniques and methods developed/modified at ICRISAT.

Technique/method	Insect pest/Disease	Remarks
Mass rearing technology	Sorghum stem borer	Transferred and adopted, by NARS in Somalia (1989), Tanzania (1990), Mali (1993)
	Helicoverpa	Established in 1985, widely adopted by NARS
Infestor/infector row	Pigeonpea sterility mosaic, shoot fly, downy mildew	Widely used by NARS
Fishmeal application	Shoot fly	Widely used by NARS
Artificial infestation/inoculation	Stem borer, downy mildew, ergot, smut	Widely used by NARS
Sowing date, split sowing	Shoot fly, sorghum midge, grain mold	Widely used by NARS
Irrigation	Aphids, grain mold, ergot, smut	
'Hot-spots', 'sick plots'	Sorghum midge, stem borer, pigeonpea wilt, phytophthora blight, chickpea wilt	Widely used by NARS
Head cage testing	Sorghum midge, head bug and pearl millet miner	Adopted by NARS in India, Africa, and USA
Crop residue destruction	Sorghum midge, stem borer, phytophthora blight	Highly effective for pearl millet stem borer

Spodoptera; malic acid in chickpea against *Helicoverpa;* glume length and apposition in sorghum resistance to midge; Flavin 4-OL in sorghum grain mold resistance; and phenolic compounds in pearl millet resistance to mildew.

Over 1500 germplasm and breeding lines have been identified as sources of resistance to insect pests and diseases of ICRISAT mandate crops (Table 2). Several of these have been used in the development of improved resistant cultivars released by NARS. Information on the extent of use by NARS and levels of adoption/cultivation by farmers, where available, is presented in Table 3.

Crop management in insect pest and disease control

Traditionally, farmers have employed crop and soil management practices which effectively kept insect- and disease-related losses below levels that required intervention. Often referred to as 'cultural control methods', they involve manipulation of sowing/harvesting dates, crop combinations and cropping patterns, crop residue management, mulching and ridging to conserve soil moisture, and the use of natural plant

Table 2. Total number of entries, and examples of sources of resistance to insect pests and diseases of sorghum, pearl millet, pigeonpea, chickpea, and groundnut identified/developed at ICRISAT.

Crop	Resistance sources[1]	Examples: Insect/Disease	Examples: Best entries
Sorghum			
Insect pests	235	Sorghum midge	DJ 6514, ICSV 745
		Head bugs (*Eurystylus*)	Malisor 84-7, CSM 388
Diseases	273	Grain mold	ISs 25017, 3547, 9470
Pearl millet			
Diseases	764	Downy mildew	700651, P 7, P 1449, WC-C75
Pigeonpea			
Insect pests	14	*Helicoverpa*	ICPL 332, ICPL 84066
Diseases	84	Sterility mosaic	ICPs 7867, 10976, 10977
Chickpea			
Insect pests	13	*Helicoverpa*	ICCV 7, ICC 506
Diseases	67	Wilt	ICCs 2862, 9023, 9032, 10803,11550,11551
Groundnut			
Insect pests	78	Termite	ICG 2271
		Leaf miner	ICGV 86031
Diseases	266	Early leaf spot	ICGs 7292, 9294, 10920

1. Total of germplasm accessions and breeding lines.

Table 3. Improved insect pest/disease resistant cultivars developed at ICRISAT, and their status as of Dec 1993.

Crop	Insect/Disease	Cultivar	Remarks
Sorghum	Midge	ICSV 197	Research initiated 1980, released in India 1986; Used extensively in breeding programs
		ICSV 745	Research initiated 1980, released in Karnataka 1993; in on-farm studies in Andhra Pradesh in 1992/93
		ICSV 88032	In AICSIP trials
	Head bug	Malisor 84-7	Research initiated 1982, released in Mali 1988
	Grain mold	E35-1, IS 9225	Selected from Intl. Nursery and released in Ethiopia 1982, 1984
Pearl millet	Downy mildew	ICMH 423	Research initiated 1978, released in India 1988
		PUSA 23	Based on ICRISAT downy mildew resistant ms 841A, developed by IARI. Adopted by farmers - 1 mha in 1993
Pigeonpea	*Helicoverpa*	ICPL 332 (Abhaya)	Research completed
	Pod fly	ICP 11964	Adopted by AICPIP as donor parent in 1990
		ICP 10531	Adopted as resistant donor in Bengal
Pigeonpea	Wilt	Maruti	Released in peninsular India - 0.5 m ha
		ICP 9145	Developed in 1987, occupies an estimated 20% of pigeonpea area in Malawi
		ICPL 87119	First multiple disease resistant pigeonpea for wilt and sterility mosaic in India
	Sterility mosaic	ICPL 87119	Released 1992
		ICPL 15	Released 1988, 1992
		Rampur	Released 1992
Chickpea	*Helicoverpa*	ICCV 7	Identified by AICPIP as donor parent in 1986
	Wilt	ICCV 2, ICCV 37, ICCV 10	Released 1990
	Ascochyta blight	ILC 3279, ILC 195, ILC 482	Released 1989

Continued....

Table 3. *Continued ....*

Crop	Insect/Disease	Cultivar	Remarks
Groundnut	Foliar diseases	ICGV 87157[1], ICGV 87160, ICGV 86590	Released 1989; resistant to rust and late leaf spot. Popular in peninsular India, coastal Andhra Pradesh, Karnataka, Tamil Nadu
	A. flavus	J 11	Popular in western India. Being released in Paraguay, 1993
	Rust	ICG 7886	Elite rust-resistant germplasm line (Tifrust) released in Jamaica in 1987

1. Not released, but grown by farmers in Maharashtra.

products. Several of these enhance natural enemy abundance within the crop ecosystem. Research into cultural practices has led to improved practices. For example, intercropping cereals and legumes reduces stem and pod borer damage; wide spacing reduces *Helicoverpa* damage; early and uniform sowing, though dependent on rainfall, reduces shoot fly, midge, stem borer, and mildew incidence; rotating pigeonpea with castor reduces *Fusarium* wilt; and destruction of crop residues reduces foliar diseases of groundnut and sorghum, and pearl millet stem borer populations.

Other approaches in non-insecticidal control

Pheromone technology. Pheromones of *Helicoverpa, Spodoptera,* leaf miner, sorghum midge, and stem borers have been identified, and monitoring procedures established. These are efficient tools in ecology studies and pest population monitoring, which are key IPM ingredients. The pheromone trap network for *Helicoverpa* has been in operation for over 10 years with strong NARS (All India Coordinated Crop Improvement Projects, AICCIP, and All India Coordinated Research Project on Oilseeds, AICORPO) involvement. The active ingredients of the pearl millet sex pheromone have been identified. Appropriate mixtures, dispensers, and a trapping device have been developed. Collaborative research with the Natural Resources Institute, UK, has advanced to on-farm testing in Niger for borer control by trapping and mating disruption.

Botanical insecticides. Biorationals or plant-derived pesticides, also referred to as botanicals, have been developed in collaboration with the Indian Institute of Chemical Technology (IICT). These are derived from neem (*Azadirachta indica*) fractions NF16 and NF20, and custard apple (*Annona cherimola*) fraction ASF 16. Tests at ICRISAT Asia Center show that these fractions are as effective as endosulfan in the control of sorghum stem borer and head bug and the army worm.

Information generation and exchange

The basic concept in plant protection research is the generation of scientific information which is targeted at the primary end-user, the farmer. The role of NARS as the conduit in the delivery system depends on the product. Data on crop loss and economic injury levels are an essential component of IPM. Such information (although incomplete) is available for several insects and diseases. Other information-related products include a forecasting model for *Spodoptera* and protocols for managing insecticide resistance in *Helicoverpa.* Constraints to the implementation of the latter are related to social, political, and funding issues.

Over 20 information and research bulletins have been published by ICRISAT on a wide range of subjects in plant protection, including identification of insect pests and diseases, and research methodologies (e.g., resistance screening and evaluation techniques) that have direct impact on NARS research capabilities. The value (and impact) of this form of technology exchange is reflected in the large number of copies and reprints distributed.

Conclusion

The products of research in plant protection are diverse, and range from research methodologies to the development of genetically improved cultivars and parental material, and the integration of an array of control options into IPM/IDM packages. To what extent have our research efforts had impact on NARS and farm productivity? Why have some technologies had little effect on NARS research programs and the farming community? How can researchers set future priorities and allocate resources to activities? To answer these and many other questions, feedback information must be obtained and channelled to research managers and scientists. It is hoped that the REIA team will help us establish an information support system that will enable us to make the right decisions. Several of the items presented in this paper should be attractive candidates for such a study.

Acknowledgement

This paper is the product of the joint effort of scientists in the Crop Protection Division in the compilation of information presented. The author takes credit only for its presentation.

Cropping Systems Research at ICRISAT

M M Anders[1]

Introduction

Historically, cropping systems research has been an important component of research at ICRISAT. A large portion of this work was carried out in the (former) Resource Management Program. However, there have been major contributions from the (former) Legumes and Cereals Programs. While research is conducted at all ICRISAT locations, this presentation focuses only on ICRISAT Asia Center.

Cropping systems research covers a very broad area from basic/strategic to adaptive, and can be classified under four categories:

- Intercropping systems;
- Sequential and relay cropping systems;
- Agroforestry cropping systems;
- New cropping systems.

The general objectives (which translate into a large number of specific research thrust areas) are:

- To develop improved or new cropping systems;
- To improve existing systems;
- To quantify existing and new cropping systems.

This research has yielded a wide range of outputs, each of which must be evaluated in a comprehensive impact study. These outputs include:

- Publications (books, information/research bulletins, journal articles);
- Conferences/workshops;
- Training programs for NARS staff and others;
- Inputs to network research (e.g., the Cereals and Legumes Asia Network);
- On-farm studies and other collaborative research.

Research studies

Several examples of cropping systems research studies are given below.

Intercropping. An exhaustive series of strategic studies was carried out on plant nutrition and spatial arrangement, nutrients and water, legume benefits, genotype identification, and yield stability. There were two broad objectives:

1. Agronomy Division, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.

- To develop improved cropping systems;
- To quantify intercropping systems.

Much of this work involved the sorghum/pigeonpea intercropping system. These studies evolved or refined methods to describe productivity in intercropping systems, most notably by introducing the concept of land equivalent ratio (LER). This work was extensively published in journals and conference proceedings, and very widely cited. Despite its quality, few examples could be found where cropping systems were tried on farmers' fields.

Intercropping combinations were included in attempts to popularize the Vertisol Technology Package, and it was reported that in one of the 'adopted' villages (Taddanpalle in Warangal district, Andhra Pradesh), an 88% increase in profit was obtained from using improved cropping systems.

Postrainy season sorghum. A number of studies were completed on postrainy season sorghum as a traditional cropping system, focusing on water use, physiological development of root systems and genotype screening. The objectives were to quantify the existing system in physiological terms, and provide recommendations for further research. This work resulted in a detailed description of the postrainy season sorghum cropping system in journal articles and conference proceedings, and specific recommendations for further research.

Pigeonpea physiology. This formed an important part of the cropping systems research at ICRISAT. Research was carried out on alternative management practices for existing cropping systems, and on the development of new systems involving short- and extra short duration pigeonpea varieties. Broadly, the objectives were:

- Multiple harvests of medium-duration pigeonpea;
- Adaptation of extra short duration pigeonpea to rainfed environments;
- Management of perennial systems;
- Introduction of pigeonpea as a winter crop, or as a replacement for other legumes.

A wide range of outputs resulted from this work. Most notable of these was the effort to reestablish pigeonpea in Sri Lanka by consolidating earlier strategic research findings, and working in concert with the Sri Lankan NARS to transfer that work to farmers' fields.

Agroforestry. This work is relatively new at ICRISAT but has received much attention in the recent past, particularly on the quantification and characterization of agroforestry systems. Initial studies focused on improving existing systems that used *Leucaena* and a mixture of intercrops. These studies dealt with plant competition (for water and light), grain and fodder production, cropping system management, and economic benefits.

Originally this work focused on quantifying plant competition in *Leucaena* intercropping systems. However, these systems had little potential, and work was therefore shifted to perennial pigeonpea, for which it was reported that great potential existed. Outputs from this work included journal articles and other publications, conference proceedings, training, and collaborative ventures. This work resulted in hundreds of seed requests (unfortunately, the fate of these requests is not known). Accounts of more strategic work, aimed at quantifying agroforestry systems, appeared as journal articles, and was also disseminated through conferences and training courses.

Recent and current research

Several studies have been initiated at ICRISAT to develop improved systems and quantify existing and new systems. Their scope includes: plant competition for water and light; grain and fodder production; cropping systems management; and economic benefits.

There has not been sufficient time to measure the impact of these studies.

Vertisol Technology in India: Technology Development, Extension, and Impact Assessment

D J Flower[1]

Research domain and production constraints

In 1981, 26 million ha of agricultural land was left fallow during the rainy-season in India. It was estimated that Vertisols of the semi-arid tropics accounted for 12 million ha of this fallow land (Ryan and Sarin 1981). Dryland agriculture in India is often constrained by the length and intensity of the discrete rainy-season. Despite assured and abundant rainfall (1300 mm in Begumgunj), grain yields of postrainy season crops were less than 1 t ha^{-1} in 1981. These yields did not reflect either the abundance of rainfall or potential length of the growing season. Hence, the rainfall-use efficiency of the traditional cropping systems was low (Kanwar et. al. 1982). Vertisols, in general, were a vast under-utilized resource whose future lay with crop intensification. It was argued that if a rainy-season crop could be grown with a modest yield of 2 t ha^{-1}, this would contribute 24 million tons to India's foodgrain production (Ryan and Sarin 1981).

It was perceived by agricultural scientists that the inability, or unwillingness, of farmers to plant a rainy season crop was associated with the poor drainage and waterlogging observed on farmers fields and difficulties associated with land preparation after the rainy season commenced (Walker et al. 1983). Vertisols, with their high clay content, are difficult to cultivate when wet. Also, after heavy rains, they drain relatively slowly, resulting in prolonged waterlogged conditions. Frequent rainfall at the start of the monsoon delays sowing and increases weed growth.

Results from informal field surveys and discussions with agricultural scientists revealed that low levels of fertilizer were being applied, and seed and fertilizer placement in farmers fields was generally poor. It was argued by concerned scientists that increases in fertilizer application were needed to increase grain and fodder yields and improve the rainfall-use efficiency. It was also well known that newly developed high-yielding varieties had a higher capacity to respond to fertilizer than the local landraces. Consequently, increased crop protection was essential to protect the extra investment of resources by farmers.

1. Agronomy Division, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.

History of technology development

A multi-disciplinary team of agricultural scientists was assembled, which had a depth of experience with crops and management practices. The team divided the research tasks into discrete components, which were to be integrated at a later stage. Many visits were made to the Vertisol areas and numerous discussions held with concerned NARS scientists. However, it is unclear from the available literature how systematic, and to what extent, diagnostic research was conducted to explore the nature and extent of production constraints. This information was necessary to confirm the initial hypotheses and to target technology development. Furthermore, with hind-sight, farmers' involvement in the initial stages of technology development and constraint identification appears limited. A package approach was considered feasible with several clusters of improved technological options to markedly increase production. Such opportunities are rare in dryland agriculture in the semi-arid tropics (Walker et al. 1983). Consequently, a package of technological options was developed in an attempt to overcome the production constraints. Two major experiments were conducted at the ICRISAT Asia Center, located at Patancheru (Anders and Sharma 1993). First, a 'Steps in technology' experiment was conducted in 1976/77 and 1977/88 on a Vertic Inceptisol. This study was to provide a single-component evaluation of selected management practices. One of the clear demonstrations in the 'Steps in technology' experiments was the interaction between fertilizer and improved sorghum genotypes (Kanwar and Rego 1983). Secondly, operational-scale demonstrations were established on two Vertisol watersheds. One site received the technology package and the other was treated in the traditional fashion. Within each of these watersheds a range of different cropping systems was examined. This was a valuable learning experience and a necessary step in technology evaluation. Between 1975 and 1988, 14 cropping systems were evaluated along with a range of management practices. Frequent changes in the cropping system, genotypes, and management systems made it difficult to compare the long-term effects of the treatments (Anders and Sharma 1993).

As a result of efforts by the multi-disciplinary team of scientists, a package of technology was developed, which became known as 'Vertisol technology'. This package was meant for Vertisol areas in regions with a relatively dependable rainfall (Figure 1) where the land was fallow during the rainy-season. The technology options developed for the management of the deep black soils were of a moderate-input nature, based on bullock power, and within the reach of a small farmer in the rainfed semi-arid tropics. They are based on the concept of a small watershed as the basic resource management unit. They were technology options that would create employment, and therefore be socially relevant. The components of the technology are:

- Cultivating the land immediately after the previous postrainy season crop when the soil still contains some moisture and is not too hard;
- Improved drainage with the aid of field and community channels and the use of graded broad-beds and furrows;
- Dry-seeding of the crops before the monsoon rains;

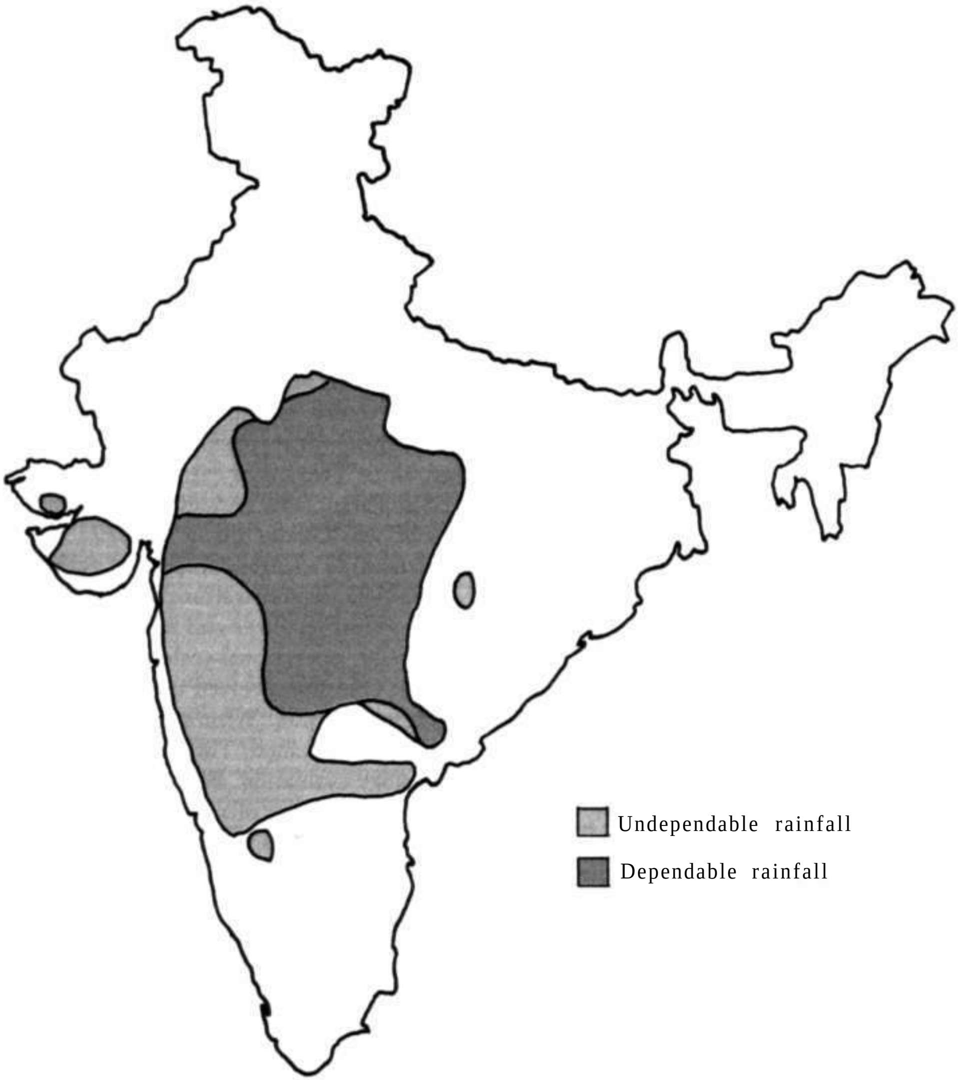

Figure 1. Vertisol areas in India, showing regions of dependable/undependable rainfall.

- The use of improved seeds and moderate amounts of fertilizer;
- Improved crop mixtures and row arrangements;
- Improved placement of seeds and fertilizers for better crop stands;
- Attention to improved plant protection, particularly for legume crops (Ryan et al. 1982.)

Results from these operational-scale demonstrations were extremely encouraging. The productivity of the improved maize/chickpea and maize/pigeonpea cropping systems was markedly higher than that of the traditional postrainy season crops of chickpea and sorghum (Table 1). These increases in grain yields were apparent in all years, even though the rainfall during the cropping period varied from 616 mm to 1089 mm. The performance of maize during the rainy-season was particularly impressive, von Oppen et al. (1985) reviewed the economic performance of the Vertisol technology at ICRISAT Asia Center over the period 1976-1984 (Table 2). Substantially higher gross returns were achieved by using the improved cropping systems and management practices—Rs 6800-8900 ha^{-1} compared to Rs 1600 ha^{-1} from the traditional system. Though the operational costs were three times as high, gross profits rose from Rs 961 ha^{-1} to Rs 4300-6400 ha^{-1} when the improved technology was employed. This increase in profit was not associated with increased risk as the coefficient of variation in the gross profits was similar for both traditional and improved technologies. Consequently, the marginal rate of return on the investment in Vertisol technology ranged from 159% to 304%, depending on the cropping system.

Table 1. Grain yields of improved and traditional cropping systems in operational-scale watersheds at ICRISAT Asia Center, 1976/77 to 1983/84 (Virmani et al. 1989).

		Improved systems				Traditional system	
	Rainfall during cropping period	Maize/chickpea sequential		Maize/pigeonpea intercrop		Single crop postrainy season	
Year	(mm)	Maize ($kg\ ha^{-1}$)	Chickpea ($kg\ ha^{-1}$)	Maize ($kg\ ha^{-1}$)	Pigeonpea ($kg\ ha^{-1}$)	Chickpea ($kg\ ha^{-1}$)	Sorghum ($kg\ ha^{-1}$)
1976/77	708	3120	650	3290	780	540	440
1977/78	616	3340	1130	2810	1320	870	380
1978/79	1089	2150	1340	2140	1170	530	560
1979/80	715	3030	590	1950	890	450	500
1980/81	751	4190	790	2920	970	600	560
1981/82	1073	3450	1320	2840	1070	1050	640
1982/83	667	3420	1380	2970	1030	1240	630
1983/84	1045	3020	2120	2780	1740	480	840
Mean	833[1]	3230	1170	2710	1120	720	570
CV(%)	25	18	43	16	27	41	25

1. Mean rainfall over 70 years (1901-70) is 760 mm, with a CV of 24%.

Table 2. Economic performance of Vertisol technology at ICRISAT Asia Center: averages of annual performances, 1976-83.

Technology/ cropping system	Mean yield ($kg\ ha^{-1}$)	Gross returns ($Rs\ ha^{-1}$)	Operational cost ($Rs\ ha^{-1}$)	Gross profits ($Rs\ ha^{-1}$)	CV of gross profits (%)	Marginal rate of return (%)
Improved technology						
Maize/pigeonpea						
Intercrop		6765	2080	4705	28	272
Maize	2712					
Pigeonpea	1121					
Maize-chickpea						
Sequence		7021	2757	4264	43	159
Maize	3205					
Chickpea	1164					
Sorghum/pigeonpea						
Intercrop		8875	2471	6404	26	304
Sorghum	2887					
Pigonpea	1088					
Traditional technology						
Rainy-season fallow,		1643	682	961	43	
Postrainy season						
Sorghum and chickpea						
Sorghum	567					
Chickpea	718					

Source: von Oppen et al. (1985)

History of technology extension

To test the performance of the technology outside the experimental station at Patancheru, on-farm trials were conducted during 1981-84 at a range of locations in the dependable-rainfall Vertisol areas of India. These trials were highly collaborative in nature and involved:

- State Departments of Agriculture;
- All India Coordinated Research Project for Dryland Agriculture; and
- Andhra Pradesh Agricultural University.

Later, the agriculture departments of Andhra Pradesh, Karnataka, Madhya Pradesh, and Maharashtra began further testing of the technology on their own initiative. The trials involved farmers trained in the new technology. They were insured against any reduction in profit incurred by adopting the new technology in the test years. Fanners had some control on the type of cropping system chosen (Foster et al. 1987). In 1983/84, the tests were extended to cover 2122 ha involving 1406 farmers in the four states (von Oppen et al. 1985). This represents a substantial investment of time, resources, and capital. Unfortunately, no comprehensive or consolidated report of this activity is available. With such a large number of farmers exposed to different components of the Vertisol technology package there was a tremendous opportunity to learn from the farmers' perceptions and experiences.

Early results obtained at field sites located near Patancheru were encouraging. ICRISAT and NARS technical staff were heavily involved in the conduct of these on-farm trials. High rates of return were obtained with the improved technology in both Taddanpally and Sultanpur (Table 3). At Kanzara, Shirapur, and Aurepalle, the performance of the improved technology was unimpressive compared to traditional farmers' practices. Test locations of Shirapur, Aurepalle, and Farhatabad were located outside the original target domain of Vertisols with assured rainfall. Any additional monetary returns at these sites were nullified by the extra input costs. Over the two years of the study at Kanzara, the improved technology offered little scope for improving farmers' incomes (Sarin and Ryan 1983). In terms of relative profitability, the improved technological options showed considerable promise in Begumgunj in 1982/83. Some of the cropping systems, particularly soybean/pigeonpea intercrop, performed well with profits over Rs 3300 ha^{-1} (Walker et al. 1983).

Table 3. Comparing the profitability of improved deep Vertisol technology options with traditional farm practices in seven watershed tests, 1979/80 to 1982/83 (Walker et al. 1983).

	Watershed test site description				
(District, State)	Year	Area (ha)	Farmers (no.)	Soil (rainfall)	Marginal rate of return (%)
Aurepalle	1979/80	13.5	5	Alfisols	Negative
(Mahaboobnagar, Andhra Pradesh)	1980/81	11.9		(unassured)	37
Shirapur	1979/80	13.9	8	Deep Vertisols	Negative
(Sholapur, Maharashtra)	1980/81	10.5		(unassured)	113
Kanzara	1979/80	3.7	3	Medium deep	Negative
(Akola, Maharashtra)	1980/81	10.8		Vertisols (assured)	8
Taddanpally	1981/82	14.5	12	Deep Vertisols	244
(Medak, Andhra Pradesh)	1982/83		4	(assured)	381
Sultanpur (Medak, Andhra Pradesh)	1982/83	26.7	12	Deep Vertisols (assured)	302
Farhatabad (Gulbarga, Karnataka)	1982/83	17.5	3	Deep Vertisols (semi-assured)	3
Begumgunj (Raisen, Madhya Pradesh)	1982/83	24.0	10	Deep Vertisols (assured)	26

Although the new management practices improved field drainage, farmers surveyed in Begumgunj were quick to point out that poor field drainage was not the only, or even the most important, constraint to rainy-season cropping in this high rainfall area. Other constraints such as lack of time, weeds, and insect pests may have been the limiting factors (Walker et al. 1983). It was concluded by Foster et al. (1987), after their study of adoption assessment in the Begumgunj area, that the current impact of dry seeding, watershed management, and interest in the wheeled tool-carrier was small but it was not completely lacking.

Prospects for assessment of impact

Vertisol technology research represents a major institutional investment by ICRISAT and NARS in India. This technology has had a far-reaching influence on donors and other agricultural agencies. The extent of this influence is an important dimension that should not be understated. As the technology was tested with more than 1400 farmers across a range of rainfall zones, it should be possible to directly measure the impact. In Begumgunj, in Madhya Pradesh, a detailed adoption assessment survey was conducted by Foster et al. (1987). Prior to ICRISAT's involvement in this area, rainy-season cropping was uncommon. By 1987, a slow but steady trend towards double cropping was apparent (Foster et al. 1987). The experience at Begumgunj with Vertisol technology highlights the difficulty in tracing the flow of information on improved management practices compared to the flow of physical products, such as seed or equipment. While the Vertisol technology was developed as a package, farmers were free to choose one or more components of the technology. This creates a difficulty in assessing the impact of this technology as these components may be applied to selected crops in selected seasons in selected fields (Foster et al. 1987).

Another problem for impact assessment arises from the concurrent flow of information from different sources. As already mentioned, one of the clear demonstrations in the 'Steps in technology' experiments was the interaction between fertilizer and improved genotypes. However, research on the rates of fertilizer application to dryland crops has been a persistent activity worldwide. Research on the fertilizer response of different cropping systems in India predates ICRISAT. Furthermore, changes in the rates of fertilizer application by Indian farmers also precedes ICRISAT's experience with Vertisol technology. Consequently, it would be difficult to precisely document the contribution of ICRISAT- and NARS-generated knowledge to the observed changes in fertilizer-use. An estimation can be made by comparing the temporal changes in the district- or *mandal*-level data from similar areas with contrasting levels of technology extension. This comparison can be coupled to a survey to identify any changes in farmers' perceptions of fertilizer-use. Similar arguments are also valid when attempting to assess the impact of supplemental irrigation.

Another important component of the Vertisol technology package was the use of a broad-bed and furrow land-surface configuration. It was well documented, both on-station and on-farm, that maize and sorghum responded markedly to the broad-bed and furrow configuration under severe waterlogged conditions. The response of other crops, particularly legumes, was not encouraging. Response of all crops was poor during the postrainy season. Experience has shown that the technology is not particularly beneficial in the drier regions. As this technology has a physical attribute, it is relatively easy to assess the level of its adoption by farmers. To my knowledge, this component was not widely used in India or other parts of the semi-arid tropics prior to ICRISAT's involvement in Vertisol technology. One measure of the impact of this technology is an estimate of the hectares of land where this configuration is used. Broad-bed and furrows are easily identified by field investigators and a simple survey of villages surrounding the Vertisol technology test sites would give a reliable estimate of adoption. A similar and concurrent approach can be used to examine the impact of dry sowing.

Conclusions

The original vision for the Vertisol areas with assured rainfall was well founded, i.e, their future lay with crop intensification. There still remains an enormous potential for improving productivity. Cropping systems in these areas are not static, e.g. the distribution of chickpea, sunflower, and soybean is currently changing. It is important for ICRISAT to recognize and anticipate these changes when refining the technology options. These options should not be restricted to ICRISAT's mandate crops alone. Central to achieving an impact is understanding farmers' perceptions of technology options and their attitudes to investments in labor and capital. This should be a central feature of any new initiatives in these Vertisol areas. Apart from the Begumgunj area, adoption assessment research is urgently needed, particularly in Taddanpally and Sultanpur, where substantial economic returns on investment in Vertisol technology were recorded. Information on adoption and farmers' perceptions is necessary to target future research activity. It is imperative that this information is collected by a multi-disciplinary team and suitably documented.

References

Anders, M.M. and Sharma, S.K. 1993. An historical perspective of Vertisol watershed research at ICRISAT 1975-1989: *Steps in technology and operational-scale demonstration studies.*

Resource Management Program, Production Agronomy Progress Report no. II. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 98 pp. (Limited distribution.)

Foster, J.H., Kshirsagar, K.G., Bhende, M.J., Bhaskar Rao, V., and Walker, T.S. 1987. Early adoption of improved Vertisol technology options and double cropping in Begumgunj, Madhya Pradesh. Resource Management Program, Economics Progress Report no. 77. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 82 pp. (Limited distribution.)

Kanwar, J.S., Kampen, J., and Virmani, S.M. 1982. Management of Vertisols for maximizing crop production—ICRISAT experience. Presented at the 12th International Congress of Soil Science, 8-16 Feb, New Delhi, India. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. (Limited distribution.)

Kanwar, J.S. and Rego, T.J. 1983. Fertilizer use and watershed management in rainfed areas for increasing crop production. Fertilizer News 28: 33-43.

Ryan, J.G. and Sarin, R. 1981. Economics of technology options for deep Vertisols in the relatively assured rainfall regions of the Indian semi-arid tropics. Presented at the Seminar on Management of Deep Black Soils, 21 May 1981, Indian Council of Agricultural Research, New Delhi. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. (Limited distribution.)

Ryan, J.G., Virmani, S.M., and Swindale, L.D. 1982. Potential technologies for deep black soils in relatively dependable rainfall regions of India. Presented at the Seminar on Innovative Technologies for Integrated Rural Development, 15-17 April 1982, New Delhi. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. (Limited distribution.)

Sarin, R. and Ryan, J.G. 1983. Economic assessment of improved watershed-based technology options in on-farm experiments. Economics Program Progress Report no. 46. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 20 pp. (Limited distribution.)

Virmani, S.M., Rao, M.R., and Srivastava, K.L. 1989. Approaches to the management of Vertisols in the semi-arid tropics: The ICRISAT experience. Presented at the Management of Vertisols for Improved Agricultural Production: Proceedings of an IBSRAM Inaugural Workshop, 18-22 Feb 1985, ICRISAT Asia Center, India. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. (Limited distribution.)

von Oppen, M., Ghodake, R.D., Kshirsagar, K.G., and Singh, R.P. 1985. Performance and transfer constraints of improved Vertisol technology. Entwicklung + Landlicher Raum 19:11-14.

Walker, T.S., Ryan, J.G., Kshirsagar, K.G., and Sarin, R. 1983. The economics of deep Vertisol technology options: implications for design, testing, and transfer. Presented at the ISAE/ICRISAT/AICRPDA seminar on Technology Options and Economic Policy for Dryland Agriculture: Potential and Challenge, 22-24 Aug 1983, ICRISAT Asia Center, India. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. (Limited distribution.)

Socioeconomics and Policy Research at ICRISAT

T G Kelley[1]

Introduction

Economists in international agricultural research centers (IARCS) work in three broad areas:

- Mainstream economics studies;
- Applied (assessment) studies;
- Research management support.

These domains are neither discipline- nor task-bound. They are client-oriented and defined as such. Though each generates the same product—information—what distinguishes them *is* the kind of information produced and the intended (primary) client.

Mainstream economics studies. These examine factor (land, labor, and credit) markets, commodity markets (supply and demand, consumer preferences, projections), risk, production relations, rural welfare, policy, and methods, among others. This research is basically carried out within the economics group.

Our clients for this research are other economists; information generated (and ultimately published in reputed economics journals) builds on and contributes to the existing body of economic theory. In some cases, the information generated may also have direct relevance to governments in less developed countries, e.g., in identifying institutional constraints to agricultural development and suggesting policy changes. Accordingly, those governments could be considered secondary clients.

Applied (assessment) studies. These include technology evaluation in an *ex ante* framework, adoption studies, characterization, and diagnostic analysis. They are often carried out in collaboration with resource management and crop improvement scientists.

The primary clients are IARC and NARS scientists. Information is generated through diagnostic surveys, economic analyses of on-farm trials, and adoption studies. This information is essential to evaluate the prospects of new technology, and determine whether research objectives coincide with farmers' needs (and if not, to suggest how research should be redirected). Adoption studies also help monitor progress and furnish information that scientists can use to make decisions, e.g., in the design or adaptation of new technology.

1. Socioeconomics and Policy Division, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.

Research management support. This includes priority setting, research resource allocation methods, impact appraisal, exploratory studies, etc. This activity aims at providing information and analysis to support management decision-making, often synthesizing information from different areas.

The clientele is varied: IARC managements (which need information to support decision-making in the medium and long term), donors (documenting our successes—and demonstrating the soundness of their earlier investments—through impact appraisal), and governments of less developed countries (convincing them to invest in research). Increasingly, economists are being called upon to provide systematically based information and more quantified assessments to support IARC managements in decision-making.

Research projects

Six major research projects conducted by ICRISAT's Socioeconomic and Policy Division are discussed below, and suggestions made on how best to assess the impact of these studies.

Risk. An experiment to measure attitudes to risk was carried out involving 330 individuals from six villages in the Indian semi-arid tropics (SAT). All farmers showed intermediate or moderate degrees of risk aversion. Attitudes were strikingly similar, despite widely different income and wealth levels. This study led to:

- Government policy recommendation—since risk and risk aversion lead to under-investment in SAT agriculture, new economic and social policies are needed to improve self-insurance or risk-diffusion;
- ICRISAT policy recommendation—risk-graded technologies for target groups of farmers are not relevant, because there is not enough difference in risk attitudes to warrant such an approach.

Protein vs yield. This study examined the trade-off between yield and protein content (some high-yielding cultivars are poor in terms of nutritive value). The nutritional status of individuals in six villages was examined to assess calorie, protein, vitamin, and mineral deficiencies in SAT diets. The major findings were:

- Calories, vitamins, and minerals were the primary deficiencies;
- Cereals are the main source of energy and nutrients in the diet;
- Productivity gains increase commodity supply and tend to lower consumer prices;
- Breeding crops for yield and yield stability should take precedence over breeding for high protein content. As a result, the latter is now a low-priority activity at ICRISAT.

Tractors. The broad objectives were to study:

- The benefits from tractorization;

- Substitution effects (where the switch from animal power to tractors is guided by factor prices) and net contribution effect (tractors have specific advantages regardless of factor prices, e.g., deeper tillage, more precision, and more timely operations);
- Whether tractors contribute to increased production without necessarily displacing labor.

It was concluded that tractors do not lead to increased cropping intensity or yield; they substitute for labor and bullock power and shift the cost advantage toward larger farms. The study led to a major policy recommendation for the government: to remove subsidies for tractors (including withdrawal of import tariff exemptions).

Herbicides. This study was undertaken to:

- Evaluate the costs and returns of different weed-control alternatives, i.e., assess the scope for herbicides to reduce costs;
- Evaluate the likely impact (e.g., potential labor displacement) of widespread herbicide use in the SAT.

It was found that herbicides were uneconomical at prevailing prices, and would remain so even if wages were to rise by 50%. There was little impact in the way of yield increases when herbicides were applied to high-value crops. As a consequence of this study, ICRISAT now accords a low priority to herbicides research.

Consumer preferences

Consumer preferences were measured with respect to varietal characteristics for ICRISAT mandate crops. The objectives were to determine:

- Whether improved varieties with higher and more stable yields also have qualities that ensure (or do not limit) consumer acceptance;
- Whether food quality as reflected in market prices is an important consideration that influences varietal adoption;
- The relative importance of evident qualities (color, seed size, mold infestation, etc.) and cryptic qualities (e.g., protein content, oil content, and recovery rate) in farmers' varietal preferences.

The outputs of this study were:

- Development of a methodology (preference index) for large-scale screening for quality measurement;
- Identification and quantification of quality characteristics associated with price and consumer preference.

This information is now used by the Directorate of Marketing for grading and pricing varieties.

Technology evaluation/Adoption assessment

Several studies were undertaken to:

- Evaluate the prospects of new technologies;
- Determine whether research objectives coincide with farmers' needs;
- Monitor progress and furnish information useful to scientists in their decision making.

Some examples of studies under this general heading:

- Early adoption of double cropping in Madhya Pradesh;
- Economics of the deep Vertisol technology options;
- Early acceptance of short-duration pigeonpea;
- Changing relative value of fodder;
- Early adoption/perceptions of pearl millet WC-C75;
- Adoption ceilings for modern coarse cereals in India.

Research Evaluation and Impact Indicators

Research Evaluation and Impact Assessment: Framework and Strategies

M C S Bantilan[1]

Introduction

It is desirable, even essential, that research be properly evaluated to judge what impact it has on its target clientele. Scientists, research managers, and funding agencies are unanimous on this point. However, research, dissemination, and technology adoption are influenced by a multitude of factors, many of them hard to quantify. It is difficult to devise a method that is comprehensive enough and sufficiently rigorous to take into account all these factors, and produce a set of objective indicators by which to quantify the value of research products. This paper outlines the framework and strategies developed for research evaluation and impact assessment (REIA) at ICRISAT.

The design of the REIA implementation plan is focused on ICRISAT product lines, a broad range of final and intermediate outputs relating to germplasm enhancement and resource management. Final products include varieties, hybrids, cultural management practices, information, and policy recommendations; whereas intermediate products are outputs of upstream research that serve as inputs to further applied or adaptive research. For example, a NARS institution engaged in developing disease-resistant cultivars depends on other research organizations such as ICRISAT for male-sterile lines, segregating materials, and resistance sources. Other products in the form of research methodologies and screening techniques may also be used as inputs for related research activities which, in turn, improve crop productivity.

Our approach to REIA is one that suits ICRISAT's needs. In the planning stage, we thoroughly examine the organization's research structure in order to understand the decision-making processes and the types of decision and information support required. We then draw upon the basic principles of economics and research evaluation methodology to build a set of indicators or measures relevant to ICRISAT's research mandate. The ultimate aim is to establish a system of support for research decision-making at all levels of management—corporate, project, or disciplinary level.

Research evaluation framework

The research evaluation framework is built upon the research and development (R and D)-adoption-impact continuum constituted by three essential building blocks:

1. Socioeconomics and Policy Division, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.

- Research investments and the research process with set objectives;
- Change in the production and consumption environment as research products are utilized;
- Improvement in research clientele's welfare.

The first building block involves research funding, research objectives, and the corresponding set of evaluation measures that allow us to determine whether or not the research objectives have been achieved. The target or product clientele is also identified. Identification of the various stages in the research process and effective generation of technical information about each stage are important steps. At each stage, we may ask various questions ... What is the probability of successfully achieving an expected milestone? Is there enough capability to achieve the objectives? Has this capability been developed in the NARS? If so, in what respect has ICRISAT a comparative advantage? We may find that ICRISAT research tends to be more strategic in Asia, but more adaptive in southern Africa. In both cases, research is undertaken considering the relative research strengths or comparative advantage at each stage of R and D.

The second essential block is improvement in farm productivity brought about by technologies derived from research. What is crucial at this stage of the continuum is adoption. Of foremost interest is the determination of whether or not a variety or a hybrid or a package of management practices has been adopted and is benefiting farmers; how parental lines, resistance sources, segregating materials, research methods, or breeding techniques are contributing to NARS R and D; how information and policy recommendations have influenced decision makers; and how these ultimately improve farm productivity. These considerations involve the determination of adoption rates and the quantification, wherever possible, of socioeconomic factors influencing farm production and consumption, including responsiveness of producers and consumers to changes in prices.

The third block of the framework relates to impact—i.e., society's welfare gains due to research. Improvement in technology eventually improves community, regional, national, and global welfare in terms of food and nutrition security, self-sufficiency, productivity, sustainability, gender equity, poverty alleviation, income distribution, export enhancement, and input replacement.

Strategies

There are alternative strategies in the search for information that can be used to measure impact. One important source of information *is* the crop breeder's files. In their filing cabinets may be found vital information: what types of breeders' seed has been distributed to universities, research stations, seed companies, and farmers, and in what quantities; and what feedback has been received from them. The seed register is a rich source of information on the volume and spread of breeders' seed. Tracking how these seeds are multiplied into foundation seed and thence into certified seed is very useful. Important to this tracking process are information from

NARS research stations on production of foundation seed and data from private/ public sector seed companies on certified seed production, marketing, and distribution. State seed corporations have season- and cultivar-wise data on the volume of foundation seed produced.

Seed certification agencies are also another source of data for tracking ICRISAT based products. For example, the All India Coordinated Pearl Millet Improvement Project (AICPMIP) collected data on the area devoted to production of certified seed of pearl millet hybrids and composites during the period 1987 to 1992. These data identify which varieties are popular, and those for which there has been a sustained demand over the years. Materials from various research stations (Indian Agricultural Research Institute, ICRISAT, Gujarat Agricultural University, and Haryana Agricultural University) are featured in the pearl millet data, with dates of release and area under certified seed production. For example, WC-C75, an ICRISAT-based pearl millet variety, was released in 1982 and became popular during the early 1980s. Certified seed is still being produced but demand is declining, and WC-C75 is being replaced by two other ICRISAT-based cultivars, ICTP 8203 and Pusa 23. This kind of information enables us to follow ICRISAT's research products as they pass through research stations, universities, seed sectors, and extension networks before finally reaching farmers. Our preliminary studies indicate the critical role that ICRISAT plays in improving the genetic population and producing parent materials, and the complementary roles of public and private sector research in the continuum. An examination of the flow of intermediate products through the continuum (pedigree development, agronomic research, on-farm trials, technology dissemination, seed production and multiplication, and ultimately adoption by farmers) brings out important information on impact and constraints, which can then help in identifying future research directions and priorities.

Another approach to illustrate the contribution of ICRISAT research is examination of the pedigrees of released materials. (This is now in progress.) Varietal release proposals, annual reports, research publications, and other documents are scanned for information about released cultivars—varietal traits, locations where they were bred, pedigrees, and dates of identification and release. Groups of parental lines are examined for homogeneity trends that indicate relatives among released cultivars. Exploratory investigations indicate that ICRISAT is a major source of breeding materials for the NARS and the seed sector. We now need to develop an indicator to measure this contribution to the scientific and farming communities.

Anecdotal evidence about ICRISAT's successful materials is available at farm level, but must be systematically verified. First, we identify the institutions and processes involved in extension and seed distribution. Second, we track seed production, multiplication, and distribution among farmers. Survey instruments have been developed to collect relevant data about seed-producing farmers, including a breakdown of this seed by end-use, e.g., for sowing on their own land, for consumption at home, for sale within the village, for sale to other villages or districts, for sale as grain, etc. These data are verified through targeted farm surveys.

Integration of data for impact measures

Data from various sources (on-station experiments and trials, frontline demonstrations, farm surveys, crop simulation models, etc.) will be integrated to form an aggregate picture of ICRISAT's role in delivering improved products to the farming community. Several types of analyses may be involved: farmer preference studies, constraint analysis, yield gap determination, and analysis of risk reduction, potential cost reduction, quality improvement, and other value added measures. Together, they provide a comprehensive way to measure the benefits due to research.

Impact indicators are built to support both *ex ante* (before research) and *ex post* (after research and technology dissemination) evaluations. *Ex ante* assessments aim to estimate the potential benefits from research to assist in planning, priority setting, and resource allocation.

Ex post impact assessment is essential to establish accountability of research investments and justify the need for more funds. What exactly was the effect of technology dissemination and adoption on the target population? To answer this, we collect information on welfare gains, constraints, needs, and opportunities. This information in turn is used to fine-tune (and redirect where necessary) future research efforts.

Various impact indicators are measured: socioeconomic, environmental, and institutional. At the farmer's level, we examine changes in productivity and welfare (income, health, nutrition, and food security). New technologies invariably affect (for better or for worse) the natural resource base; we address the issue of agricultural sustainability, including the effects of new technologies on soil fertility, soil structure, and water quality. We also consider institutional changes to examine how (or to what extent) research institutions achieve a relatively stronger research capability with increased research investments. The role of government policy is also considered: subsidies and interventions by government are often a major factor, and could significantly reduce the impact of research.

Conclusions

We need to generate more research funds to justify the re-opening of programs (e.g., LASIP) or maintain existing ones, and to establish better accountability among our stakeholders. To properly direct (or redirect) our research efforts, we need to clearly document both our successes and our failures. Evidence of the importance of low-input technologies in the semi-arid tropics (SAT); gender roles in new technologies and their impact on family welfare; sustainability of SAT cropping systems; and development of improved short-duration cultivars for yield stability and food security are some examples of the essential feedback required in the research process. The role of resource management cannot be overemphasized. A review of ICRISAT's resource management research should determine where, how, and why such research has succeeded. Only then can we identify specific areas where substantial productivity can be achieved even without introducing new cultivars, and direct our research efforts at enhancing the complementarities between resource management and genetic enhancement.

All these aspects are essential to set priorities for the future and to optimize the allocation of our limited research resources.

Efficiency as an Indicator for impact Assessment

P K Joshi[1]

Introduction

One of the most important and widely used indicators in impact assessment is efficiency. It refers to increase in productivity, decline in input cost, or expansion of area or scale of production. Research improves the quality of agricultural inputs by either introducing improved technology (e.g., cultivars and chemicals) or by generating new concepts and/or information. These research outputs contribute to enhanced efficiency in the following ways:

- Overcoming or alleviating biotic and abiotic constraints;
- Allowing the substitution of expensive and often scarce resources with cheaper and more abundant inputs;
- Improving labor skills and management techniques.

Constraint removal through the use of research products involves a measure of technical efficiency—achieving higher outputs with the same level of measurable inputs, or the same output with fewer inputs. When a research product induces farmers to use more resources to further increase output, it effectively causes an increase in the scale of output due to a change in technology. Improvement in efficiency can take several forms:

- Increased production;
- Decreased cost;
- Higher surpluses for consumers and producers;
- Saving of foreign exchange by reducing imports;
- Higher exports.

Measurement of efficiency

Efficiency is measured as a ratio of output to input. Various approaches to the measurement of efficiency are discussed in the literature, and may be grouped into two broad categories:

- Computation of factor productivity by developing indices of outputs and inputs;
- Estimation of production relations using econometric techniques.

1. Socioeconomics and Policy Division, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.

Factor productivity. The simplest measure of efficiency is partial productivity, which is the average product of land, labor, or capital. It is computed as:

$AP_L = Q/L$, $AP_K = Q/K$

where AP = partial productivity, Q = output, L = labor, and K = capital.

However, this approach ignores the presence of other factors that influence partial productivity. A more sophisticated measure of efficiency reflects (in the form of appropriate weightages) the extent of technical progress. This measure is the total (multi) factor productivity, often referred to as the 'residual'. It is defined as output per unit of combined inputs, and is measured as:

$$A = Q/(aL + bK)$$

where A is total factor productivity, a and b are appropriate weights, and Q, L, and K are as defined above.

Two approaches have been developed to estimate total factor productivity:

- Kendrick's arithmetic measure, which uses linear aggregation of various inputs with market factor prices as weights;
- Solow's geometric measure, which uses geometrical aggregation with factor shares as weights.

Econometric approach. Different forms of production and cost functions are estimated to compute the rate of returns on investment in agricultural research. The production and cost functions are also decomposed to derive the contribution of research in enhancing production, reducing input costs and output prices, and generating producer/consumer surpluses.

Earlier studies

Several studies have been conducted to measure increase in productivity and savings in resources/foreign exchange resulting from reduction of imports and generation of consumer/producer surpluses. Important studies include those by Solow (1957), Griliches (1958), Evenson (1973), Evenson and Jha (1973), Akino and Hayami (1975), and Davis et al. (1987). All the studies confirm that investment in agricultural research is an important source of agricultural growth.

References

Akino, M. and Hayami, Y. 1975. Social returns to agricultural research investment. American Journal of Agricultural Economics 57(l):l-5.

Davis, J.S., Oram, P.A., and Ryan, J.G. 1987. Assessment of agricultural research priorities: an international perspective. Monograph no. 4. Canberra, Australia: Australian Centre for International Agricultural Research.

Evenson, R.E. 1973. The Indian agricultural research system and its contribution to agricultural production. Connecticut, USA: Economic Growth Center, Yale University. (Limited distribution.)

Evenson, R.E., and Jha, D. 1973. The contribution of the agricultural research system to agricultural production in India. Indian Journal of Agricultural Economics 28(4):212-230.

Griliches, Z. 1958. Research costs and social returns: hybrid corn and related innovations. Journal of Political Economy 66:419-431.

Solow, R.M. 1957. Technical change and the aggregate production function. Review of Economics and Statistics 39:312-320.

Indicators of Food and Nutrition Security— What Use are They to ICRISAT?

Kimberly Chung[1]

The mission statement of the Consultative Group on International Agricultural Research (CGIAR) says clearly that we exist to: 'contribute to sustainable improvements in the productivity of agriculture ... in ways that enhance the nutrition and well-being of low-income people.' It is therefore important that we define what we mean by 'nutrition and well-being' and that we know how to measure and monitor it.

'Food security' is a working definition that underlies the idea of 'nutrition and well-being'. Food security is a state in which sufficient food is available at all times to all people, to ensure an active and healthy life. Sufficiency refers to both the quantity and quality of food required for good health. The term 'food security' has been used at the national, regional, community, household, and individual levels. Its essential elements are the availability of food and the ability to acquire it.

Traditional indicators

We are interested in measuring and monitoring food security because it represents one of the most basic requirements of human life. Operationally, how do we measure it? Traditionally, nutritionists have measured food security by collecting dietary records and comparing food intake with the prescribed dietary requirements. Economists, on the other hand, often collect data on household expenditures or income, and express per capita total expenditures, per capita food expenditures, and the food budget share as indicators of a household's food security status. Nutritionists tend to take the individual as the unit of analysis while economists tend to focus on the household. In either case, these 'traditional' indicators are often collected at the micro level, and the process is both time consuming and expensive.

Alternative indicators

A collaborative study at ICRISAT is focusing on field testing alternative indicators of food and nutrition security. The objective of this study is to identify indicators that are valid and reliable, and yet straightforward and inexpensive to collect and analyze. Several such indicators have been derived from data from the Philippines, Brazil, Ghana, and Mexico:

1. Socioeconomics and Policy Division, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.

Effects of technology—a case study

A case study analyzing the effects of alternative technology intervention on real income and poverty was undertaken by Evenson et al. (1993) for targeted population groups (farm occupational groups and low-income decile groups) in rural Philippines. Using a CGE Impact Multiplier model, policy simulations were undertaken to determine the impact of two simulated changes—a 10% increase in rice research, and a 10% increase in all agricultural technology.

For a hypothetical 10% increase in budgets for rice research (including research at the International Rice Research Institute and elsewhere on high-yielding varieties), the study showed:

- Increased supply of both rice and corn;
- Increased demand for labor, fertilizer, and agricultural machinery;
- Reduced use of animal power;
- Higher real incomes for all rural groups, with the largest benefits to owner-cultivators;
- Relatively equal increases in real income for the general population.

Had research and extension budgets for all crops been 10% larger, we would have:

- Increased production of rice and corn;
- Reduction in the use of agricultural labor (presumably due to relative labor-using bias);
- Increased demand for fertilizer and machinery;
- No change in the use of animal power;
- Lower real incomes for landless workers;
- Higher incomes for tenants;
- Large increases in owner-cultivator incomes;
- Higher real incomes in deciles 1 (urban poor) and 7-10 (urban rich), largely because these groups benefit from lower food prices whereas their incomes are not significantly affected.

In general, the study showed that more funding for rice research would improve the welfare of the rural landless, a special sub-class of the rural poor. The decile simulations showed that absolute poverty (as measured by real income effects for the lowest deciles) could be reduced if more technologies were developed (for rice or other crops).

Relative poverty or general income distribution effects were not strong for either simulation. General technological improvements appeared to benefit the poorest and the richest more than the middle class. However, these simulations were generally consistent with broader findings on rural poverty, namely policies that reduce poverty are general growth policies that tend to increase all incomes. Economic growth reduces absolute poverty but has little effect on income distribution.

Reference

Evenson, R.E., Quisumbing, A., and Bantilan, M.C.S. 1993. Population, technology and rural poverty in the Philippines: rural income implications from a simple CGE Impact Multiplier Model. Pages 47-72 *in* Perspectives on Philippine Poverty. Manila, Philippines: Center for Integrative and Development Studies, University of the Philippines and Connecticut, USA: Council of Southeast Asian Studies, Yale University.

Risk and Stability

J M Kerr[1]

Introduction

Risk in agricultural production is related to stability. If production and prices are stable over time, there is no risk. But agricultural production is inherently unstable and therefore risky. This is so especially in the semi-arid tropics due to the variable weather.

Stability of agricultural production refers to the degree of variation in output. A stable variety, for example, gives a roughly constant yield, while an unstable variety might give a wide range of yields depending on prevailing conditions.

The simplest indicator of instability and risk is the probability distribution of crop production levels. If production is normally distributed, the coefficient of variation associated with the mean production indicates the level of stability.

Risk, stability, and variance

Risk is exposure to possible loss. It is associated with the probability of obtaining a range of different outcomes. Risk in agriculture stems mainly from variability in production and price. Production risk is due mainly to fluctuations in weather and attacks by pests and diseases. Price risk is caused by the unpredictability of market forces.

Some new high-yielding varieties are highly responsive to water and fertilizer. In a good year they give very high yields, but in a bad year they might give nothing. Some traditional varieties, on the other hand, might be unresponsive to fertilizer and water but also insensitive to drought, and so provide low but stable yields.

The mean-variance relationships of improved agricultural technologies have important implications for risk. For example, a new variety is characterized by low risk if it yields the same minimum amount in a dry year as does a local variety, but gives a much higher yield in a wet year. This means that the low end of yield probabilities is stable while the high end is variable (Figure 1). Another example would be a pest- or disease-resistant variety that is not susceptible to catastrophic losses. In contrast, unstable production is characterized by both high- and low-end instability.

Another possibility is high-end stability and low-end variability relative to traditional varieties (Figure 1). Obviously, this is a situation most farmers would prefer to avoid.

1. Socioeconomics and Policy Division, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.

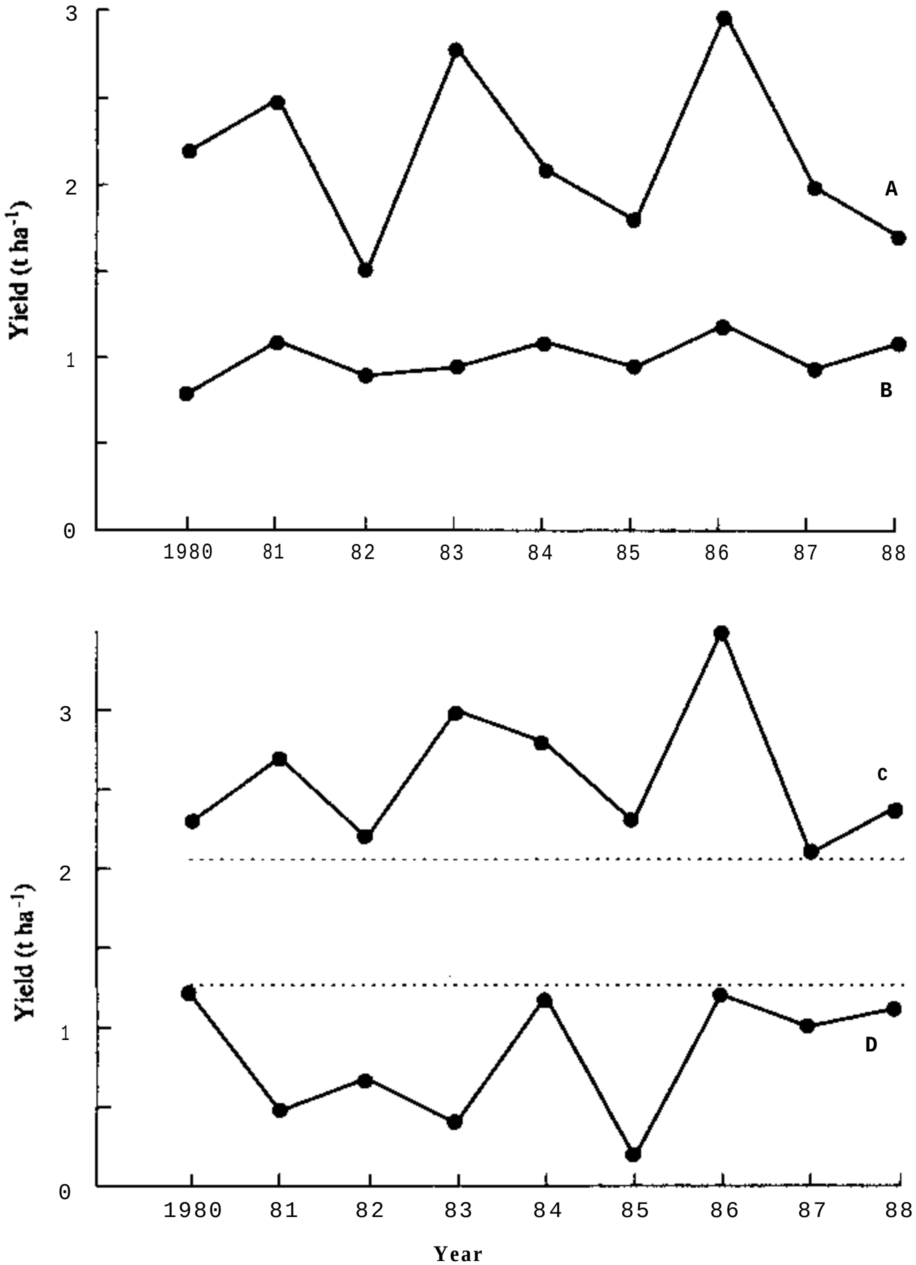

***Figure 1.** Examples of stability and variance in crop yields. A. High mean, high variance;* **B.** *Low mean, low variance; C. Low-end stability with high-end variability; D. Low-end variability with high-end stability.*

Income and risk

As mentioned above, price risk results from changing market conditions. In the aggregate, price is negatively correlated with supply, with good harvests leading to lower prices. This helps to smoothen variations in agricultural income in the aggregate—but, unfortunately, not necessarily for an individual farmer. However, if a farmer has a bad production year when everyone else has had a good year, that farmer's low output will be compounded by low prices.

Variations in income resulting from price and production risk are known as income risk. Farmers can reduce income risk by diversifying their sources of income. It is very common for farmers in the SAT to have diverse sources of income, including non-agricultural income. They can also diversify their agricultural production by cultivating several plots, or multiple crops on each plot. Crop insurance programs can compensate farmers if they suffer losses owing to reasons beyond their control, but in practice it is very difficult to successfully manage crop insurance schemes.

Risk and technology adoption

It is important to distinguish between risk and uncertainty. Risk is a matter of probability. Farmers face risk if they have a rough idea of the probability distribution of rainfall. Uncertainty, on the other hand, involves unknowns and lack of information, e.g., about the seed characteristics of a newly introduced variety.

How does risk affect adoption of new technology? Will farmers adopt new varieties that are more profitable on average but subject to greater risk of loss? It depends in part on farmers' attitudes toward risk. Farmers who are averse to risk will choose technology that minimizes their exposure to possible loss, even if it means foregoing a probable but uncertain higher outcome. Those who are risk-seeking take chances to get possible high payoffs. Risk-neutral farmers choose on the basis of expected value, preferring a high-mean, high-variance option to a low-mean, low-variance option.

Impact Indicators: Sustainability

Meri L Whitaker[1]

Introduction

To define indicators of sustainability we must begin by defining the issues:

'Sustainability ... means the ability to maintain or increase food production over the long term. In [ICRISAT's] case, this requires that the resource base on which crops are produced—the fragile environment of the SAT—must not be damaged in the push for higher yields' (ICRISAT 1991).

'Can agricultural production in the SAT be increased to meet the needs of expanding populations without threatening the resource base on which food supplies depend?' (ICRISAT 1991).

New technology and sustainability

In the context of the two quotations above, ICRISAT researchers must ask two questions while assessing the impact of new technology on sustainability. In the adoption of new technology,

- Is the resource base enhanced, maintained, or degraded?
- Are the achieved levels of agricultural production sustainable over the long term?

Indicators

What are appropriate indicators of sustainability? First, indicators of sustainability are by definition *trends in time* and should include:

- Baseline data;
- Expected range;
- Anticipated outcomes from interactions between components;
- Data over time.

Second, they should have some *general characteristics of good indicators;* they should be:

- Measurable (qualitatively or quantitatively);
- Reliable (could two people interpret the same data differently?);
- Cost-effective;

1. Socioeconomics and Policy Division, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.

- Suitable for measuring changes in the resource base;
- Suitable for measuring changes in outcomes (e.g., agricultural productivity).

These indicators could include indexes or proxies.

Examples of possible sustainability indicators

Changes in the resource base could be measured by soil quality indicators (Table 1).

Table 1. Soil quality parameters as indicators of sustainability.

Physical parameters	Chemical parameters	Biological parameters
Texture/depth	Total organic C and N	Microbial biomass
Bulk density	pH	Potential mineral N
Infiltration	Electrical conductivity	Soil respiration
Water-holding capacity	Mineral N, P, K	
Water retention		
Water content/temperature		

Source: Doran et al. 1990.

More aggregate indicators could include:

- Indexes of soil and water quality;
- Soil salinity;
- Acidification;
- Organic matter;
- Water use;
- Erosion and sediment transport;
- Off-site losses of agricultural chemicals.

Changes in outcomes (e.g., agricultural productivity) could be measured in terms of:

- Land use;
- Cropping rotations and crop species;
- Types and levels of inputs;
- Trends and variability in yields;
- Cattle/sheep/goat numbers and ratios;
- Trends and variability in costs and value of farm production;
- Total factor productivity.

Data sources for indicators

For the purpose of monitoring the impact of new technology on sustainability, information on trends in agricultural productivity might well be adequate, since our ultimate interest is in the sustainability of food production. But ICRISAT cannot afford to wait 10 or 25 or 100 years for productivity differences to appear. Nor do we want to learn about sustainability problems only when a technology fails in farmers' fields. Thus, assessing the impact of new technology on sustainability involves peering into the future. Indicators for the purpose of prediction could come from:

- Secondary statistics on trends in productivity;
- Long-term technology evaluation studies at benchmark sites and on farmers' fields, which can provide information on interactions between technology, the agricultural resource base, and productivity;
- Crop and land management simulation models that can extrapolate experimental results across time and space.

References

Doran, J., Varvel, G.E., and Culley, J.L.B. 1993. Tillage and residue management effects on soil quality and sustainable land management. Pages 59-74 *in* Sustainable land management for the 21st century, vol. 2 (Wood, R.C. and Dumanski, J., eds.). Lethbridge, Canada: University of Lethbridge.

ICRISAT. 1991. Pathways to progress in the semi-arid tropics: ICRISAT's strategic plan for the nineties. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 82 pp.

Gender as a Socioeconomic Variable in Impact Assessment

Ramadevi Kolli[1]

An agricultural scientist's primary concern while designing technologies is to raise crop yields, either by varietal improvement or by developing improved, cost-effective methods of crop and resource management. However, socioeconomic aspects, which play a crucial role in successful technology transfer, are often overlooked. These socioeconomic aspects include labor availability or the availability of special skills or knowledge required to apply the new technology; and such institutional aspects as availability of inputs, extension capabilities, etc. One key variable that could determine the successful adoption of technologies is gender.

Scientists designing or developing technologies for agriculture often lack information on the gender division of labor, resource allocation, and distribution of benefits. This lack of information is often responsible for non-adoption of technologies—women play important decision-making roles at both household and farm level, and enough consideration must be given to their preferences and concerns. Failing to do so would, in the long run, create inequalities among the beneficiaries of new technology and also affect the 'efficiency' of technology generation and dissemination, because women would tend to operate less efficiently under a 'gender-biased' technology.

Gender perspectives in impact assessment

Non-adoption of new technologies has long been a serious problem in semi-arid environments. In recent times, social scientists have stepped up efforts to diagnose the problems related to adoption, by conducting *ex ante* and *ex post* assessments in conjunction with agricultural scientists, tracking and evaluating technologies from generation through transfer and use.

Impact assessment of technologies could be short- or long-term, and could vary from simple yield gains analysis to more complicated analyses of net gains in family and social welfare. For each type of assessment, appropriate indicators that reflect a gender perspective are required. These indicators will necessarily be somewhat different for the different types of assessment; what is needed is to identify the most effective indicators in each case, and the best methods to apply them.

1. Socioeconomics and Policy Division, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.

Case studies

The use of gender as a socioeconomic variable is a fairly recent phenomenon, but several studies have demonstrated the importance of integrating gender concerns into agricultural research and extension. For example, glutinous rice and snacks are sold widely in the Philippines, but their preparation involves considerable drudgery for women. This was specifically addressed by introducing high-yielding glutinous rice varieties to increase women's incomes, and by modifying processing units to reduce the drudgery. A study of varietal preferences in Columbia changed breeders' opinions about bean varieties; women's preferences were found to have a considerable influence on which beans were purchased for household consumption.

ICRISAT is currently involved in two studies on gender analysis. In collaboration with the Central Research Institute for Dryland Agriculture, we are examining the differential effects of technology intervention on inter- and intra-household dynamics. We are also conducting an *ex post* evaluation of groundnut technology (improved varieties and management practices) that is now widely adopted in parts of Maharashtra. The technology was introduced in 1987 by ICRISAT's Legumes On-farm Testing Network (LEGOFTEN) program, and has resulted in substantial gains in yields, incomes, and employment. We are now focusing on the impact of this technology on labor and resource allocation, and the distribution of the benefits across and within families.

Factor Endowments

M Asokan[1]

Introduction

Factor endowments (land, labor, capital, etc.) are important in the design of new technology for agriculture. The appropriateness of a technology—and thus its adoption by farmers—is determined in part by the factor endowments among its target clientele. In many cases, a technology may fail to be widely adopted because factor endowments were not properly assessed while designing the technology (e.g., an otherwise suitable technology that is too expensive or requires more labor than is available).

In an *ex ante* and *ex post* framework, researchers and administrators need to know the substitution possibilities among different production functions with equal factor-intensity characteristics but different relative factor prices.

Comparative advantage

Factor endowments are inequitably distributed among farms in India. About 75% of the holdings are small (<2 ha), and together constitute only 30% of the total cultivated land. In contrast, about 10% of the holdings are large (>4 ha), but account for 50% of the cultivated land. However, farmers in a given ecosystem and subject to a given set of constraints try to efficiently allocate their resources. Small farms use more labor and less capital, while large farms use less labor and more capital to produce a given level of output. Thus the notion of comparative advantage comes into play: farms with high labor-to-land or labor-to-capital ratios would adopt more of labor-using techniques. On the other hand, farms with low labor-to-land or labor-to-capital would tend to use more of labor-saving techniques.

Factor endowments and new technology

Technology is an important factor in agricultural growth. The adoption of new technology is influenced by factor endowments and relative factor prices. Farmers do augment the supply of scarce factors such as land, labor, and capital. There is an increasing demand at national and international levels for the development of technologies specifically designed to benefit operators of small farms. The basic premise

1. Socioeconomics and Policy Division, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.

behind this objective, in the context of Hayami and Ruttan's (1971) Induced Innovation Hypothesis, is that the resource endowments of small farms differ substantially from those of large farms in a way analogous to differences in endowments between countries. For example, countries with low person-to-land ratios (e.g., USA and Australia) developed their agricultural sectors by employing land-using and labor-saving technological innovations. In contrast, Japan, with a high person-to-land ratio, relied on biological innovations of a land-saving type.

In the Indian context, some researchers have argued that technological change, in the form of the green revolution, favored large farms; others found the technology to be scale-neutral. Many researchers emphasize the need to design technology specifically for small farmers. But are factor ratios indeed significantly different between farm-size groups? Using ICRISAT Village Level Studies (VLS) data for 1975/76, Ryan and Rathore (1978) found no significant differences in factor ratios between small and large farms, and concluded that it was not necessary to design different technology for small farms.

Using ICRISAT VLS data for the period 1975/76 to 1984/85, Walker and Ryan (1990) came to the same conclusion. However, they found that household mean factor use ratios for a given farm-size group were significantly different in different regions of the country. This led to the conclusion that a region should be the focus for technology design.

Preliminary analysis of 1989/90 VLS data showed significant differences in mean factor use ratios (land-to-labor) in three villages: Shirapur and Kalman in Solapur district, Maharashtra, and Rampura in Sabarkanta district, Gujarat. However, further studies are required to determine, for example, the influence of differences in land quality, availability of irrigation, etc.

References

Hayami, Y. and Ruttan, V.W. 1971. Agricultural development: an international perspective. Revised edition. Baltimore, USA: Johns Hopkins University Press. 506 pp.

Ryan, J.G. and Rathore, M.S. 1978. Factor proportions, factor market access, and the development and transfer of technology. Hyderabad, India: Economics Program, International Crops Research Institute for the Semi-arid Tropics. (Limited distribution.) 34 pp.

Walker, T.S. and Ryan, J.G. 1990. Village and household economies in India's semi-arid tropics. Baltimore, USA: Johns Hopkins University Press. 416 pp.

Spillover Effects of Agricultural Research

M C S Bantilan[1]

Introduction

Research spillover effect is an important aspect of research evaluation, and has been dealt with extensively in the literature. A technological breakthrough leads to increased yields, or improves the quality of output, or enhances the efficiency of input use. The new technology may have applicability beyond the confines of the location for which it was generated, or beyond the commodity for which it was developed. These effects are commonly referred to as spillover effects; different types are distinguished in agricultural research literature (Bantilan and Davis 1991).

The first type involves across-location spillovers, 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 applicability of the new technology may not be the same for all production environments, since these may be governed by different agronomic, climatological, and ecological factors.

The second type of spillover effect refers to across-commodity applicability of the technology developed. For example, a cultural management technique developed specifically for sorghum production may also have the potential to improve the efficiency of production of millets and other cereals.

The nature of these two types of spillover effects reflects the direct applicability of a technology across different locations/production environments and across different commodities. They are therefore referred to as direct spillover effects.

The third type of spillover effect is referred to as the indirect or price spillover effect. Because technological change for a particular commodity at a specific location increases supply and may cause price changes, the price effect at other locations (if the commodities are traded) or on related commodities at the same location may have significance. This is particularly relevant for products with low demand elasticity, and/or when the rate of product transformation among commodities is significant.

Spillover effects and research management decisions

The importance of the spillover concept is being increasingly recognized in recent years (Davis 1991), mainly for three reasons.

First, the concept of spillover clarifies research policy issues regarding government investment in agricultural research, especially in cases where the private sector is unable to appropriate a major share of the potential gains from research.

1. Socioeconomics and Policy Division, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.

Second, it is useful to assess the extent of spillovers while deciding whether to focus attention on developing technologies to maximize production efficiency in specific production environments, or to maximize smaller productivity gains over a wider range of production environments. Since the mandates of most research planners and managers usually cover many different (and often diverse) production conditions or environments, trade-offs are inevitable while selecting a production environment on which to focus research. The wider the range of production environments to which research results can be applied, the easier will these choices be for managers. The levels of these applicabilities or spillovers (which are unlikely to be similar across different environments) can influence the choice of among options.

Third, inclusion of the spillover component in research impact assessments facilitates subdivision of production regimes into homogeneous regions, thereby satisfying a fundamental condition in research evaluation.

Quantifying spillover effects

Several studies have addressed the problem of estimating spillover effects empirically. Aggregate studies by Evenson (1978, 1989) estimated a relationship between research expenditure at one location on the output at other locations by specifying an aggregate production function with a public research expenditure variable. These aggregate studies provide useful information for general research policy considerations. A case study by Brennan (1986) estimated significant economic gains to Australia from a specific wheat technology developed by the Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT). Edwards and Freebairn (1984) and Mullen et al. (1989) used a two-region spillover model, i.e., one country versus the rest of the world, to estimate a spillover index. Davis et al. (1987) extended the Edwards/Freebairn model to include many regions and agroclimatic zones to delineate agricultural production environments. This methodology has been applied to forestry research and to a number of commodities (including fisheries and livestock) in several other countries (e.g., Bantilan and Davis 1991, Davis et al. 1989).

In these applications, the fundamental concepts in the generation of empirical estimates involve:

- Choice of production environment classification system;
- Empirical estimation or elicitation of estimates of potential spillover effects.

Usually, improvement in production efficiency is measured in terms of the cost-saving impact of research from the originating production environment to other environments where the research output or technology is applicable. In this case, a normalized measure is obtained, where the unit cost-saving in the environment where research is conducted is defined as unity, and the spillover impact, or degree of applicability to other environments, varies from zero to unity.

References

Bantilan, M.C.S. and Davis, J.S. 1991. Across-commodity spillover effects of research and opportunity costs in a multi-product production environment. ACIAR/ISNAR Project Papers no. 30. Canberra, Australia: Australian Centre for International Agricultural Research. 21 pp.

Brennan, J.P. 1986. Impact of wheat varieties from CIMMYT on Australian wheat production. Agricultural Economics Bulletin no. 5. Queensland, Australia: Department of Agriculture, New South Wales. 15 pp.

Davis, J.S. 1991. Spillover effects of agricultural research: importance for research policy and incorporation in research evaluation models. ACIAR/ISNAR Project Papers no. 32. Canberra, Australia: Australian Centre for International Agricultural Research. 17 pp.

Davis, J., McKenney, D., and Turubull, J. 1989. Potential gains from forestry research and a comparison with agricultural commodities: a preliminary assessment. ACIAR/ISNAR Project Paper no. 15. Canberra, Australia: Australian Centre for International Agricultural Research. 40 pp.

Davis, J.S., Oram, P.A., and Ryan, J.G. 1987. Assessment of agricultural research priorities: an international perspective. Monograph no. 4. Canberra, Australia: Australian Centre for International Agricultural Research. 85 pp.

Edwards, G.W. and Freebairn, J.W. 1984. Gains from research from tradeable commodities. American Journal of Agricultural Economics 66(324):41—49.

Evenson, R.E. 1978. A century of productivity change in U.S. agriculture: an analysis of the role of invention, research and extension. Center Discussion Paper no. 296. New Haven, Connecticut: Economic Growth Center, Yale University.

Evenson, R.E. 1989. Spillover benefits of agricultural research: evidence from US experience. American Journal of Agricultural Economics 71(2):447-452.

Mullen, J.D., Alston, J.M., and Wohlgenant, M.K. 1989. The impact of farm and processing research on the Australian wool industry. Australian Journal of Agricultural Economics 33(l):32-47.

Impact Assessment: Case Studies

Distributional Impact of Research: Sectoral Benefits and Policy Simulation

M C S Bantilan[1]

Introduction

Results from a simple impact multiplier model are used to illustrate the possible distributional consequences of changes in technology. The model consists of producer and consumer cores for the agricultural sector. The consumer core is an abstraction of the utility-maximization behavior of consumers, and provides the demand equations for products in the market. The producer core embodies the profit-maximizing behavior of farmers, and yields the output supply and factor demand equations for the model. This provides the link in the model between technology and agricultural markets.

The model is used to analyze the impacts of price policies, population growth, and technological shocks on changes in market equilibrium prices and quantities. The effects on equilibrium prices and quantities in both product and input markets are translated into changes in nominal and real incomes of specific sectors or population groups. This fundamental approach provides an effective way to determine the price implications of technological changes for incomes and poverty.

Distributional impacts—a case study

A case study for rural Philippines is presented, based on a series of studies consolidated by Evenson et al. (1993). It includes input markets for labor, machinery, fertilizer, animal power, and land. The product markets include rice, maize, coconut, sugar, fruits, livestock, fish, processed foods, nonfood goods, transportation, and services.

Four 'shift' factors are considered: technology, population, labor force growth and migration, and capital and infrastructure. These shift factors are captured in the product supply and factor demand equations, under the condition of maximized producer's profit. Equilibrium growth rates of the prices of labor and capital are derived from these equations to reflect the equilibrium price paths of labor and capital which respond to changes in each of the shift parameters.

Changes in policy variables are associated with changes in equilibrium price paths and quantities. Thus, these price paths are useful for policy analysis of technology impacts. For example, when demand is elastic, more rapid technological change is associated with higher rates of change in the price of labor and/or capital. The reverse

1. Socioeconomics and Policy Division, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.

holds with inelastic demand. Moreover, changes in factor prices lead to changes in nominal incomes, depending on ownership of factors by various sectors, while the distribution of gains among different sectors depends on relative supply responsiveness.

Research investment is considered as a policy variable in this case study. Estimates of technology elasticities are obtained from two sets of results. Bantilan (1986) provided an estimate that utilized the high-yielding varieties (HYV) 'generation' variable in a farm-level sample. The estimate from Evenson (1986) used regional data, where separate estimates were obtained for research and HYV adoption/extension.

The case study reports the following impacts of alternative technology shocks on real incomes of farm occupational groups and selected income groups:

- An increase in research investment increases real incomes of all rural occupational groups: owner-cultivators, tenants, and landless workers, with the largest benefits accruing to owner-cultivators;
- Larger research and extension programs tend to reduce incomes of a special subclass of the rural poor—the landless workers;
- In a segmented labor market, labor in the disadvantaged region will be harmed by technological gains in the advantaged region as long as demand is not perfectly elastic. However, when labor is mobile, it may gain from technological change in the advantaged region as long as demand is elastic.

The gains of the labor sector depend on the mobility of labor. These gains arise from increased labor demand with the adoption of improved technologies (due to higher cropping intensity, higher labor requirements, and growth linkage effects on non-farm employment). Higher labor demand induces interregional migration from unfavorable to favorable regions, which helps to equalize wages across production environments. There is therefore no strong evidence that differential technology adoption reduces the incomes of landless laborers.

References

Bantilan, M.C.S. 1986. Production analysis: econometric issues. Journal of Philippine Development 13(1 and 2):77-99.

Evenson, R.E. 1986. Infrastructure, output supply and input demand in Philippine agriculture: provisional estimates. Working Paper. Manila, Philippines: Philippine Institute of Development Studies.

Evenson, R.E., Quisumbing, A., and Bantilan, M.C.S. 1993. Population, technology and rural poverty in the Philippines: rural income implications from a simple CGE Impact Multiplier Model. Pages 47-72 *in* Perspectives on Philippine Poverty. Manila, Philippines: Center for Integrative and Development Studies, University of the Philippines and New Haven, Connecticut: Council of Southeast Asian Studies, Yale University.

Introducing Improved Genetic Material in Crop-Livestock Systems: a Case Study in Warangal District, Andhra Pradesh

M M Anders[1]

It must first be understood that this approach is not necessarily new, nor has it been developed by a single individual working on one project. A case study is presented, involving the introduction of a wide range of sorghum varieties into three villages (Bachannapet, Chinna Ramcherla, and Itkyalpalli) in Warangal district. The methodology used is a combination of standard 'on-farm' techniques along with modifications unique to this project, and others from a similar collaborative project on pearl millet in Rajasthan, India.

Several features characterize this methodology.

- Emphasis on information flow from the farm;
- Cropping system structure (to set priorities);
- Single-component and stepwise technology transfer (a structured introduction of a single technology);
- No subsidies (each technology must stand on its own as soon as possible);
- Stratified farmer selection (to verify farmer-neutral technologies);
- Research followed by constraint removal (once farmers select a variety, sufficient seed is supplied to a restricted area to measure impact).

Sorghum was selected for this study for two main reasons. First, the focus was on fodder, and a major constraint to fodder availability is insufficient sorghum production. Second, sorghum production was declining, partly due to government subsidies that influenced farmers to choose rice and oilseed crops.

To establish a flow of information from farmers, extensive crop-livestock surveys were conducted. In addition, census data were collected from three villages, and farmers were grouped into different categories on the basis of holding size and other factors. Soil fertility and crop yields were measured. Whenever possible, farmers' perceptions were verified through measurements or experiments.

We used a 'cluster' approach, where a group of farmers was selected with land holdings reasonably close together, and each farmer was supplied with one new cultivar. This allowed farmers within each cluster to compare, throughout the experiment, the performance of different varieties. Farmers were selected from a stratified sample which represented the land holding distribution in the village. They were urged to use normal management practices, thus allowing us to more clearly measure genotype effects. In addition, detailed surveys were conducted on previous manage-

1. Agronomy Division, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.

ment practices, while current plots were carefully monitored. To ensure reasonably frequent contact with farmers, local villagers were hired to interview farmers and to collect data on plant growth (height, number of green leaves, and index of leaf size) from half the plots every 2 weeks. Measurements were taken (through survey responses) that could be related to farmers' perceptions.

A total of nine genotypes—ICSVs 112, 743, and 745, SP 260, SPV 442, SPV 462, M 35-1, N 1, and a local variety—were evaluated for two seasons in six clusters. Two cultivars (ICSV 743 and SPV 462) were found unsuitable in the first season; they were replaced by new cultivars (SP 260 and M 35-1) for the next season.

The major objective of this study was to increase fodder production. To determine whether farmers would accept dual-purpose sorghum, varieties were chosen that ranged from pure grain to pure fodder types. Additional variation existed in duration and seed size. This spectrum offered farmers a wide range of choices, and researchers a better understanding of those choices.

It was found that farmers showed less biased management and plot selection if they were supplied seed before they selected the land where specific crops would be sown. At mid-season, farmers were formally interviewed to identify problems if any, and compare the local varieties with the new experimental cultivars. Most farmers had visited other plots in the cluster and could make detailed comparisons.

At harvest, crop-cut samples were taken from all experimental plots. Additional samples were collected from fields of farmers who were not enrolled in the program. This was supplemented with a postharvest survey conducted among participating farmers and a random sample of farmers in each cluster area. This survey focused on farmers' estimates of yield, their perceptions of problems and benefits of their experimental variety, and their willingness to sow the variety for another season.

Postharvest activities included a short survey asking farmers to compare grain and fodder quality (including acceptance by livestock) in the traditional and experimental cultivars. Fodder samples were collected for quality analysis.

During the first two years of the project a total of nine varieties were evaluated, of which the farmers selected two (ICSV 112 and ICSV 745). Only small amounts of seed were supplied to participating farmers, insufficient to provide an accurate estimate of potential adoption and associated problems. Therefore, approximately 2.5 t of seed was distributed in 1993. Demand far exceeded expectations; approximately 280 kits (4 kg sorghum + 1 kg pigeonpea) were sold at subsidized prices. A season of below-average rainfall provided a good test for the experimental cultivars.

The two improved cultivars gave higher and more stable yields than the local cultivars. Mean yields from 'good' fields: approximately 2.2 t ha^{-1} grain and 8.4 t ha^{-1} fodder for ICSV 112; 2.8 t ha^{-1} grain and 7.7 t ha^{-1} fodder for ICSV 745; and 1.6 t ha^{-1} grain and 6.3 t ha^{-1} fodder for the local variety. Standard deviation values were nearly 10% higher for the local cultivars than for the improved cultivars. The percentages of leaf, stem, husk, and grain in the above-ground biomass (dry weights) indicated that the improved cultivars partitioned less to stems and more to grain when compared to the traditional cultivars. Farmers were aware that the improved cultivars contained less stem material, but still preferred the improved cultivars because of grain and fodder yields, and leaf size and number.

To further supplement these data a feeding trial will be conducted in 1994, comparing ICSV 112, ICSV 745, and the local cultivar. A set number of cattle will be fed only one cultivar for a 10-day period. Feed intake and milk production will be monitored. Our collaborator and funding agency for this study (the Indo-Swiss Livestock Project) have purchased 5 t of seed from this area and will distribute about 1500 kits to farmers. Initial introductions will be made at approximately eight new locations where the seed will be sold at half price. Seed made available to project areas will be sold at full price.

One important constraint is the farmers' inability to maintain pure seed of the introduced cultivars. Traditionally, farmers select seed from the threshing floor; throughout this experiment, they were unable to distinguish among seeds of different cultivars. To help farmers maintain the cultivars they have selected, training in seed selection and harvesting is currently under way.

Economic Evaluation, Farmers' Perceptions, and Impact of Seed Distribution in Warangal District, Andhra Pradesh: a Case Study

M Asokan[1]

Earlier studies have indicated a high preference for sorghum varieties ICSV 745 and ICSV 112 among the farmers of Bachannapet and neighboring villages in Warangal district, Andhra Pradesh. The major constraint in this region was the availability of good seed. In response to farmers' requests, it was decided to make available sufficient quantities of ICSV 745 and ICSV 112 seed for sowing in the 1993 rainy season, and evaluate the potential adoption of those two varieties. A total of 2.5 t seed was distributed (as seed kits) to farmers in these villages in collaboration with the Indo-Swiss Project. Information was received about 240 kits (Table 1).

Table 1. Number of sorghum (ICSV 745 and ICSV 112) seed kits[1] distributed in Warangal district for rainy-season sowing, 1993.

Village	ICSV 112	ICSV 745	Total
Bachannapet	40	27	67
Pochannapet	42	38	80
Itikalampally	12	9	21
Chinna Ram cherla	16	6	22
Yeddugudam	13	3	16
Thammadapally	5	3	8
Nakkavarigudam	5	3	8
Alimpoor	11	7	18
Total	144	96	240

1. Each seed kit contained 4 kg of sorghum and 1 kg of pigeonpea.

The REIA team undertook a survey after the harvest of the crop in 1993, with the following objectives:

- To evaluate the performance of ICSV 745 and ICSV 112;
- To assess farmers' perceptions;
- To determine the extent of adoption and spread of the two varieties.

1. Socioeconomics and Policy Division, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.

We tried to trace all the 240 seed kits distributed: 142 farmers bought 164 kits for themselves; 48 farmers bought kits but did not sow the seed; 6 farmers were from outlying villages and were therefore not interviewed; and 22 farmers (listed as having purchased kits) said that others had probably bought the seed on their name.

The preliminary analysis focused on Pochannapet village, where 80 seed kits were distributed. Most of the seed had been used. Twenty-two farmers had sown ICSV 112, 13 had sown ICSV 745, and 3 had sown both. For comparison, we also interviewed 15 farmers who did not buy the kits. Results of the economic evaluation of ICSV 112, ICSV 745, and the local varieties are summarized in Table 2.

ICSV 112 provided higher grain and fodder yields, and higher net returns, than either ICSV 745 or the local varieties. However, ICSV 745 received appreciably less fertilizer than the other varieties (Table 3). Production costs were lower for the ICRISAT varieties than for the local varieties, although all received similar management practices. Farmers' perceptions of ICSV 112 and ICSV 745 are listed in

Table 2. Economics of ICSV 112, ICSV 745, and local sorghum varieties, Warangal district, rainy-season 1993.

Input/output	ICSV 112	ICSV 745	Local varieties
Number of plots	22	15	19
Average area (ha)	0.46	0.60	0.51
Total labor cost (Rs ha^{-1})	4552 (41)	2572 (25)	2867 (21)
Cost of input (Rs ha^{1})			
Seed	37 (22)	30 (22)	57 (25)
Manure	348(149)	113(125)	396 (97)
Fertilizer	470 (50)	163 (104)	350 (53)
Total	5408 (45)	2878 (25)	3671 (22)
Grain yield (t ha^{1})	3.46 (45)	1.55(51)	1.47(30)
Value of grain (Rs ha^{1})	10881 (52)	5223 (63)	4254 (33)
Fodder yield (t ha^{-1})	7.8 (40)	4.7 (35)	*6.6* (23)
Value of fodder (Rs ha^{-1})	3426 (37)	2185(38)	3141 (25)
Gross returns (Rs ha^{1})	14307(44)	7408(51)	7396 (27)
Net returns (Rs ha^{*1})	8899 (63)	4530 (80)	3725 (49)
Cost of production (Rs kg^{-1})	15.60	18.60	25.00

Figures in parentheses show CV (%)

Table 3. Number of plots treated with fertilizer and farmyard manure (FYM), Warangal district, rainy season 1993.

Input	ICSV 112	ICSV 745	Local
Fertilizer	12 (55)	4 (27)	10 (53)
FYM	4 (18)	3 (20)	6 (32)
Total number of plots	22 (100)	15 (100)	19 (100)

Figures in parentheses show percentage of total number of plots.

Table 4. High grain yield and a large number of leaves (for fodder) were the most preferred characteristics. Grain mold seems to be a major problem in these varieties. Nearly all (97%) the farmers sampled said they would sow ICSV 745 and/or ICSV 112 the following season (which would increase the area under these varieties by about 53%). We expect that in the 1994 rainy season, ICSV 112 and ICSV 745 will occupy approximately 33 ha in Pochannapet village alone.

Table 4. Farmers' perceptions of ICRISAT varieties.

Component	Preferred characters	Problems
Grain	High yield Large panicle White seed color 'Sweet' taste	Grain mold Small seed size
Fodder	More leaves Broader leaves Good palatability High yield	Shorter than local variety Breaks easily Thick stem

Economic Evaluation and Adoption of Groundnut Production Technology in Tuban, Indonesia: a Case Study

K V Subba Rao[1]

Background

Indonesia has 630 000 ha under groundnut, and produces 820 000 t with an average yield of 1.3 t ha^{-1}. Tuban district in East Java province is one of the target areas for on-farm adaptive research (OFAR) on groundnut production technology. Tuban has a total cultivated area of 56 000 ha (of which 60% is rainfed), and accounts for 30% of the groundnut production in the province.

Large scale OFAR trials were conducted in Tunah village (Semanding subdistrict), 7 km from Tuban. The village has 280 ha of upland, 131 ha of lowland, and 27 ha of orchards. Land distribution is highly skewed. Rice is grown primarily in the lowlands during the wet season and the first dry season (Feb-May). Rice and maize are grown in the uplands during the wet season. Groundnut is grown on uplands during the first dry season, mainly intercropped with maize or cassava. Farmers use the local variety Tuban (duration 85-95 days). Seed rate is 100-120 kg ha^{-1} during the dry season and slightly less during the wet season. Farmers use their own seed. The haulms are not sold but used as cattle feed.

Fertilizers and manure are commonly used for rice and maize whereas groundnut is largely unfertilized. Only one weeding is done (3 weeks after sowing), usually by women labor. The common diseases are late leaf spot, rust, and peanut stripe. Thrips, aphids, and termites are common, particularly during long drought spells. Disease and pest incidence is low during the wet season.

Objectives

- To compare the economic performance of the recommended technology package with current/traditional practices;
- To assess the expected adoption of the technology.

Recommended package of practices

During the Asian Grain Legumes On-farm Research (AGLOR) Project review and planning meetings, it was decided to implement the medium-input package in large-

1. Socioeconomics and Policy Division, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.

scale on-farm trials during the 1993 dry season. These trials were conducted in Tunah village on an area of 25,5 ha owned by 66 participating farmers. Fertilizers and fungicides were given free to small and marginal farmers. The recommended package included information on nutrition management, disease and pest control, weed control, and optimum plant spacing. Details of the package are given in Table 1.

Table 1. Groundnut production technology: package of agronomic practices, Tuban, Indonesia, 1993.

Practice/Technology component	Recommended package	Farmers' practice
Tillage	Plowing and harrowing	Plowing
Plant spacing	40 x 10 cm	Irregular
Variety	Local Tuban	Local Tuban
Seed rate (kg ha^{-1})	80	120
Number of weedings	Two (2 and 4 weeks after sowing)	One (3 weeks after sowing)
Fertilizer application (kg ha^{-1})		
Urea	50	-
Triple superphosphate	75	-
Potash	25	-
Pest and disease control		
Furadan® (kg ha^{-1})	10	-
Dursban® (L ha^{-1})	1	-
Topsin-M® (kg ha^{-1})	1 (7 and 9 weeks after sowing)	

Economic analysis

The analysis is based on a monitoring tour and a questionnaire survey conducted among 20 participating and 14 non-participating sample farmers by the Malang Research Institute for Food Crops (MARIF). Data on labor requirement (including bullock labor) and wage rates for different agricultural operations, input use (fertilizers and pesticides), and input and output prices were collected to estimate the costs of cultivation for both the new technology and the traditional methods. The medium-input package was found to be superior to the existing management practices (Table 2). The new package gave 120% higher yield and 335% higher net income, and generated 36% additional employment compared to the existing practices (Table 3). The reduction in production cost was Rupaiah (Rp) 188 kg^{-1} (2000 Rp = 1 US$). Both participating and non-participating farmers expressed the view that the technology increased grain yields, improved fodder quality, increased market prices, and provided better control of diseases and pests (Table 4).

Table 2. Comparison of inputs and outputs between the recommended technology package and farmers' practices, Tuban, Indonesia, 1993.

Item	Recommended technology	Percentage of total cost	Farmers' practices	Percentage of total cost
Labor inputs (days ha^{-1})				
Male	28.2	12	27.6	14
Female	103.1	36	65	27
Bullock	18.8	9	18.1	11
Material inputs (ha^{1})				
Seed (kg)	80	22	120	40
Manure (t)	5.4	4	10.2	8
Urea (kg)	50	2	0	0
Triple superphosphate (kg)	75	4	0	0
Potash (potasium chloride) (kg)	50	3	0	0
Furadan® (kg)	10	3	0	0
Topsin-M® (kg)	1	3	0	0
Dursban® (L)	1	2	0	0
Total cost ('000 Rp ha^{-1})	711	100	599	100
Pod yield (t ha^{-1})	3.3		1.5	
Gross returns ('000 Rp ha^{1})	1959		886	
Net returns ('000 Rp ha^{-1})	1248		287	
Unit cost (Rp kg^{-1})	218		406	

Table 3. Benefits from the medium-input groundnut technology package, Tuban, Indonesia, 1993.

Item	Benefit from technology (% change from traditional practices)
Yield	+ 120
Net returns	+335
Employment (mandays)	+ 36
Cost of cultivation	+ 19
Unit cost of production	-47

Adoption

Most of the participating farmers learnt about the technology from MARIF and the government extension agency. Progressive farmers were the main motivators for initiating the OFAR program in Tuban. Sample farmers were asked whether they would adopt the technology package the following year. All were willing, provided

Table 4. Farmers' perceptions of the medium-input groundnut technology package, Tuban, Indonesia, 1993.

Perception	Participating farmers (%)	Non-participating farmers (%)
High grain yield	100	100
Good market price	75	30
Disease resistance	75	80
Good fodder quality	20	0

the subsidy was continued. If the subsidy were to be withdrawn, only 51% of participating farmers expected to continue using the complete package. The others said they would either use parts of the package (33% of participating farmers), or discontinue its use altogether (16%). Of the non-participating farmers, 68% expressed their intention to adopt a few components of the technology; the rest were not interested in any component of the technology.

The main reasons reported for this reluctance (Table 5) were capital constraints (fertilizers, pesticides, and seed, which must be paid for in ready cash, together constitute over 40% of the cost of cultivation) and non-availability of fungicides (particularly Topsin-M®). While credit facilities are available for other crops, farmers are not provided credit for growing groundnut. The existing cooperative system does not provide adequate support.

Table 5. Farmers' reasons for non-adoption of medium-input groundnut technology package, Tuban, Indonesia, 1993.

Constraint	Participating farmers (%)	Non-participating farmers (%)
Lack of capital	60	85
Non-availability of fungicides	5	15
No reason	35	0

Impact of the Cereals and Legumes Asia Network (CLAN)

C L L Gowda[1], M C S Bantilan[2], and P K Joshi[2]

Introduction

The Cereals and Legumes Asia Network (CLAN) was established to enhance research collaboration among scientists from the network's 11 member-countries through collaborative research and the exchange of information, materials, and technology. CLAN is a unified network for Asia, formed by amalgamating the Asian Grain Legumes Network (AGLN) and the Cooperative Cereals Research Network (CCRN). Two surveys were conducted to assess the contribution of CLAN (erstwhile AGLN) in alleviating constraints and increasing production of ICRISAT's mandate legume crops (chickpea, pigeonpea, and groundnut) in Asia. The first was a benchmark survey conducted in 1989 to collect basic and descriptive information from participating NARS; the second was a detailed survey undertaken in 1993 to elicit responses from Country Coordinators regarding the benefits from specific CLAN activities (e.g., technologies introduced through the network), and the expected adoption and adoption-ceiling levels for these technologies.

The responses provided fairly adequate qualitative information. Quantitative information was, however, often incomplete, and attempts are in progress to collect additional information. The impact of CLAN activities on NARS research in the member countries can be assessed in terms of the various activities coordinated by the network.

Exchange of germplasm and breeding material

This activity was reported to be substantial, particularly for groundnut (Table 1). For chickpea and pigeonpea, germplasm exchange was reported to be 'moderate'; the reasons are limited research interest in these two crops in Southeast Asia and the existence of other means (e.g., bilateral exchange with other countries) of exchanging germplasm and breeding material.

Human resource development

Most member countries acknowledged that the network provides significant training opportunities for NARS scientists and technicians. Between 1986 and 1993, 460

1. Cereals and Legumes Asia Network, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.
2. Socioeconomics and Policy Division, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.

Table 1. Number of samples of germplasm and breeding material of chickpea, pigeonpea, and groundnut distributed to CLAN member countries, 1991–93.

	Chickpea				Pigeonpea				Groundnut			
Country	Germ-plasm	Trials	Released and advanced lines	Others	Germ-plasm	Trials	Released and advanced lines	Others	Germ-plasm	Trials	Released and advanced lines	Others
Bangladesh	101	21	193	257	–	–	34	4	226	5	11	9
China	–	10	6	16	–	–	19	4	193	–	17	–
India	6672	240	791	2391	4893	259	1538	459	3265	47	1394	587
Indonesia	–	–	9	1	34	10	29	4	138	7	24	3
Myanmar	111	26	19	39	68	6	33	4	500	7	19	1
Nepal	1025	9	33	100	–	26	12	–	–	8	84	3
Pakistan	2	41	6	221	–	–	–	–	–	3	1	–
Philippines	–	4	22	16	–	–	29	2	–	–	39	6
Sri Lanka	–	–	–	–	26	13	102	117	10	7	77	–
Thailand	–	–	2	1	–	8	26	13	501	3	72	15
Vietnam	–	5	12	4	–	–	11	–	523	37	145	11
Total	7911	356	1093	3046	5021	322	1833	607	5356	124	1883	635

researchers (research fellows, postdoctoral fellows, in-service trainees, apprentices, and national scientists) underwent training at ICRISAT Asia Center. The problems associated with this activity are largely bureaucratic (e.g., visa clearance by government authorities, or delayed responses/nomination of trainees by NARS).

Information exchange

The network provided considerable support to information exchange through meetings, study tours, literature exchange, and co-publications, although this activity was not uniform across all member-countries because of funding constraints and other reasons. The responses were so positive that this activity would be expanded in future.

Support to research programs

CLAN provides support for meetings, experimentation, purchase of supplies and equipment, and specialist consultancy services to national research programs. Responses on the impact of these services were variable, probably due to differences in expectations and perceptions among member-countries. However, about 80% of the countries felt that support for laboratory and field experimentation was adequate, and *66%* emphasized that consultancy and specialist support have greatly helped to strengthen (and sometimes reorganize) NARS research programs.

Coordination of regional research, and contacts among scientists

More than 90% of the respondents felt that the network activities had improved interactions among scientists within their country, and with scientists at ICRISAT and elsewhere in the network. More than 65% characterized the regional meetings, working groups, and study tours organized by the network as being adequate to 'very good', while the remaining felt that these activities need to be further emphasized.

Technology exchange and cultivar releases

About 50 varieties have been released by NARS throughout Asia, from the material supplied through ICRISAT's international trials and nurseries. Other varieties are in the pre-release stage (Table 2). In chickpea, although improvement in yield was not significant, the achievement of yield stability has minimized farmers' risks from diseases, pests, drought, and cold. The new pigeonpea varieties have substantially increased yield levels—by 15-37% in Myanmar, 25% in Indonesia, and 10-20% in India.

Table 2. Chickpea, pigeonpea, and groundnut varieties released or found promising in CLAN member countries.

Country	Chickpea		Pigeonpea		Groundnut	
	Released	Promising[1]	Released	Promising	Released	Promising
Bangladesh	3	7	-	2	-	2
China	-	-	-	-	-	5
India	7	6	8	2	13	8
Indonesia	-	-	1	2	-	1
Myanmar	2	7	-	2	3	4
Nepal	4	4	2	3	-	3
Pakistan	-	1	2	-	3	2
Philippines	-	1	1	2	-	2
Sri Lanka	-	-	-	2	-	1
Thailand	-	-	-	5	-	-
Vietnam	-	-	-	-	1	4

1. 'Promising' refers to lines in advanced on-station/on-farm testing prior to being proposed for release.

Apart from high-yielding and disease-resistant varieties, several agronomic and pest management practices developed by ICRISAT (e.g., broad beds, application of fertilizers and lime, pest control options) are being utilized by the member-countries. Yield increases of 15-30% have been reported as a result of these technologies. Improved agronomic practices and pest control technologies increased groundnut yields in southern Vietnam by 10-20%. In many cases, the significantly shorter duration (by 20-80 days) of the new varieties has enabled farmers to avoid terminal drought stress, or to fit the short-duration varieties in existing or new cropping systems.

Conclusions

Overall, the network has been successful in building links among its members, enabling them to interact more effectively and to exchange material, information, and technology. The member countries have benefitted from the exchange of germplasm and breeding material, as is evident from the number of varieties released for cultivation. Training of NARS scientists has enhanced NARS research capabilities, and technical and financial help provided through CLAN has strengthened research infrastructure in several Asian countries.

The Country Coordinators have suggested improvements or expansion of several network activities—in-country and specialized training, exchange of scientists, on-farm research, sharing of information and technology, and involvement of research administrators in exchange programs. The network Coordination Unit will endeavor to implement these suggestions to make the network more viable and responsive to the needs of its members.

Resource Management and Technology Evaluation: a Case Study

P K Joshi[1]

Introduction

Research on crop and resource management (CRM) plays a significant part in accelerating the rate of agricultural growth, while ensuring sustainability by improving input-use efficiency. Very few studies have been carried out in the past to measure the returns from CRM research largely because it is difficult to assess (or quantify) the benefits from such research and the contribution of CRM research to overall productivity increases. The problems are:

- Identifying new products developed through CRM research;
- Assessing whether or not a research product has been adopted by its clientele;
- Establishing a causal link between research efforts and, for example, the adoption of improved management practices.

Approach

Unlike the simple approach of estimating the area under improved cultivars, assessing the adoption of CRM research outputs is rather complex. Often, the improved CRM strategies are adopted only partially by farmers, or modified depending on their resources, knowledge, or convenience. Six steps are suggested to evaluate the impact of CRM technologies (Traxler and Byerlee 1992):

- Identify the recommended components of the technology;
- Determine the practices that farmers have modified in a manner consistent with the new recommendation;
- Determine whether the revised recommendation has been the cause of change in farmers' practices;
- Disaggregate the level of technology adoption as low, moderate, or high for different components by different clientele;
- Measure the impact of each research-induced change in cropping practices on economic surplus, defined in terms of productivity, income, input saving, food security, employment generation, sustainability, etc;
- Sum economic surplus across practices and compare the benefit stream to the cost of CRM research and extension.

1. Socioeconomics and Policy Division, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.

Case studies

To illustrate the assessment of CRM technologies, three case studies are discussed below:

- Chemical amelioration of salt-affected soils;
- Subsurface drainage technology;
- Afforestation.

Reconnaissance surveys were undertaken in Haryana, Gujarat, Punjab, and Uttar Pradesh to assess the adoption of these resource management practices and their impact on crop production. An area of about 7 million ha in India is salt-affected. Two 'problem' areas are identified, on the basis of the nature of salts in the soil and the management practices in use—alkaline soils containing undissolved salts, and saline soils rich in dissolved salts. Strategic and adaptive research was initiated in the mid 1960s to reclaim and manage both types of soils. The recommendations (Table 1), which were largely adopted by farmers, were:

- Crop production and afforestation on alkaline soils rehabilitated by the application of soil amendments and other resource management practices;
- Crop production on saline soils reclaimed and managed by installing subsurface drainage.

Table 1. Recommendations from resource management research for salt-affected soils, northwestern India.

Soil type	Purpose of reclamation	Principal ammendment/ management practice	Crops/forest species
Alkaline	Crop production	Gypsum	Rice, wheat
Alkaline	Afforestation	Gypsum, farmyard manure	*Prosopis juliflora, Acacia nilotica*
Saline	Crop production	Subsurface drainage	Cotton-wheat, pearl millet-wheat, pearl millet-mustard.

The impact of these technologies/management practices was assessed in terms of changes in productivity, income, cropping intensity, employment, and income disparity. Chemical amelioration led to area increases of 18-66% for rice and 15-57% for wheat in different districts of Punjab. Land 'reclaimed' by applying these technologies contributed 26% of the total food grain production in Punjab and 18% in Haryana (Joshi and Datta 1990). A range of impact indicators also showed that these three research products contributed significantly in generating surpluses and increasing employment opportunities (Table 2).

Three sustainability indicators—soil improvement, rainwater conservation, and soil nutrient efficiency—were also assessed to measure changes in the quality of natural resources. The results are summarized as follows:

Soil improvement. The adoption of improved resource management practices improved soil quality. For example, chemical amelioration for crop production reduced the soil pH from 10.6 to 8.4 and afforestation of salt-affected soils reduced the soil pH from 10.3 to 9.9.

Rainwater conservation. With the adoption of improved practices, a large quantity of rainwater that was earlier lost as run-off was conserved, and the groundwater thus recharged. Chemical amelioration of salt-affected soils for crop production improved groundwater recharge, and 40%.of the irrigation requirements were met by improving infiltration. Afforestation on salt-affected soils enhanced the infiltration rate from 3.29 to 4.68 cm/24 h.

Soil nutrients. Improved management practices enhance soil fertility by contributing nutrients to the soil. It was estimated that by growing 1 ha of *Acacia nilotica,* 112 t of animal dung was saved, which would have otherwise been used as fuel. The nutrient contribution was equivalent to 400 kg of nitrogenous fertilizer, 170 kg of phosphorus, and 220 kg of potash.

Table 2. Impact indicators for three resource management technologies, northwestern India.

Indicator	Chemical amelioration[1]	Drainage[2]	Afforestation[3]
Annual income (Rs ha^{-1})	6000	7500	1500
Benefit:cost ratio	1.42	1.26	1.63
IRR (%)	26	13.3	n.a.[4]
Cropping intensity (%)	200	105	-
Employment (days ha^{1})	135	125	146
Equity ratio	0.306-0.186	n.a.	0.28-0.19
Inter-sectoral linkages (%)	50	60	n.a.

Sources: 1. Joshi and Datta (1990), 2. Datta and Joshi (1993), 3. Abrol and Joshi (1984), 4. n.a. = data not available.

References

Abrol, LP. and Joshi, P.K. 1984. Economic viability of reclamation of alkali lands with special reference to agriculture and forestry. Pages 125-134 *in* Proceedings of a seminar on Economics of Wasteland Development, New Delhi, 8-10 Mar 1984. New Delhi, India: Society for Promotion of Wasteland Development.

Datta, K.K. and Joshi, P.K. 1993. Problems and prospects of cooperatives in managing degraded lands. Economic and Political Weekly 28 (12 and 13):A 16-24.

Joshi, P.K. and Datta, K.K. (1990). Temporal and spatial differences in utilizing degraded lands in the Indo-Gangetic region. Indian Journal of Agricultural Economics XLV (4):468-476.

Traxler, G. and Byerlee, D. (1992). Economic returns to crop management research in the post-Green Revolution setting. American Journal of Agricultural Economics 74(3):573-582.

Concluding Session

Workplans and Recommendations

M C S Bantilan[1]

Four working groups were organized to identify appropriate technologies for impact assessment and constraint analyses, and the methodologies and information required for such an evaluation.

- Cereals (sorghum and pearl millet) germplasm enhancement group;
- Legumes (chickpea, pigeonpea, and groundnut) germplasm enhancement group;
- Crop and resource management group;
- Socioeconomics and policy group.

The groups discussed various aspects relating to the REIA workplan: identification of intermediate and final products, specific research objectives, methodologies, locations for the REIA study, survey instruments, and impact parameters. The recommendations of each Working Group are summarized below.

Cereals Germplasm Enhancement: Sorghum

Three specific genotypes, which are widely used in India, were presented as possible candidates for impact evaluation:

- CSH 14
- ICSV 745
- NTJ 2

The objectives suggested for the impact study were:

- To quantify the area of cultivation, and yields of grain and stover relative to the best available alternative;
- To quantify relative grain and stover market prices;
- To study the economics of seed production;
- To determine farmers' perceptions of varietal characteristics that encourage/discourage adoption.

To accomplish these objectives it was suggested that primary and secondary data be gathered for each genotype from the following locations/areas:

CSH 14	Northern Maharashtra
ICSV 745	Karnataka, Andhra Pradesh
NTJ 2	Andhra Pradesh

1. Socioeconomics and Policy Division, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.

It was felt that the appropriate information could be obtained through monitoring tours and correspondence with key individuals. Data will be collected on cultivated areas, grain and stover yields, seed production (area, yields, and costs), and seed distribution channels. The following key contact institutions/individuals were suggested:

CSH 14 Punjabrao Krishi Vidyapeeth, Akola, Maharashtra State Seeds Corporation, National Research Centre for Sorghum.

ICSV 745 University of Agricultural Sciences, Dharwad, Indo-Swiss Project, ICRISAT Asia Center, A P State Seeds Corporation (for NTJ 2), Andhra Pradesh Agricultural University.

Two genotypes that were expected to show good potential but had not been widely adopted were ICSV 112 and ICSH 153. It was felt that these could be evaluated:

- To determine constraints to adoption caused by farmers' perceptions and seed production/storage problems;
- To assess their utilization as parent materials in NARS breeding programs.

To meet these objectives it will not be necessary to conduct field visits; information can be gathered through personal contacts. Suggested locations to be investigated were in Mexico, Nicaragua, and Zimbabwe for ICSV 112.

Appropriate contacts suggested are the All India Coordinated Sorghum Improvement Project (AICSIP), National Research Centre for Sorghum (NRCS), the relevant state seed corporations, and Mahendra Hybrid Seeds.

The REIA target indicators discussed here deal with the major 'introduction' areas for cereals. ICRISAT has also been involved as a partner in the Cereals and Legumes Asia Network (CLAN) in the successful introduction of sorghum into new areas, e.g., in Myanmar. These introductions could be considered for impact analysis in terms of spillover effects.

Cereals Germplasm Enhancement: Pearl Millet

It was decided that direct impact can be measured by investigating the following genotypes:

- ICMH 451
- Pusa 23
- ICTP 8203
- WC-C75
- MLBH 104

To properly quantify the impact of these genotypes, the following objectives will be essential:

- To quantify the area of cultivation, and yields of grain and stover relative to the best available alternative;
- To quantify relative grain and stover market prices;

- To study the economics of seed production and use of breeders' seed;
- To determine farmers' perceptions of varietal characteristics that encourage/discourage adoption;
- To estimate changes in inherent productivity of cultivated land and changes in area, cropping patterns, and management practices.

The necessary primary and secondary data could be collected from the following areas/countries:

ICMH 451	Gujarat, eastern Rajasthan, Zambia (ZPMV 1)
Pusa 23	Gujarat, eastern Rajasthan
ICTP 8203	Maharashtra, Namibia (Okashana 1)
WC-C75	Tamil Nadu, Maharashtra
MLBH 104	Maharashtra

The data to be collected from monitoring tours and correspondence are cultivated areas, grain and stover yields, seed production (area, yields, and costs), and seed distribution channels.

The following key contact individuals/institutions were suggested: ICRISAT staff (Pearl Millet Breeding Unit), the REIA team, All India Coordinated Pearl Millet Improvement Project and Indian Agricultural Research Institute (IARI) staff, Maharashtra State Seed Corporation, Mahenclra Hybrid Seeds, A P State Seeds Development Corporation, and the Gujarat State Seeds Cooperative Marketing Federation.

In addition to the five genotypes, it was suggested that the REIA team should look at the methodology being used to introduce RCB IC 911 into Rajasthan.

Product-use was thought to be a constraint to the wider adoption of pearl millet genotypes. In crops such as pearl millet, productivity increases have been obtained through research, partly compensating for the decline in total area under cultivation. Ideally, impact/constraint analyses should provide information on shifts to other crops and on management changes. However, for many projects, the cost of collecting this information will be high. Incorporating an evaluation structure into each future project can ensure that such information is collected. This in turn requires the development of low-cost methodologies for impact assessment.

Legumes Germplasm Enhancement

The technologies presented here are of two types: varieties and intermediate products. The overall objectives of the assessment of these technologies are:

Varieties

- To study adoption trends;
- To examine the factors affecting adoption;
- To compare the adoption of varieties in different regions/states.

Intermediate products

- To investigate collaborative breeding programs for:
  - comparison with individual programs;
  - examining the utilization of parental materials, segregating materials, and breeding lines;
  - comparing polygon and other breeding approaches;
  - developing varieties/hybrids from intermediate products.

The methodologies suggested are surveys, consultancies, networks, monitoring tours, visits, and collaboration with NARS, nongovernmental organizations, international and regional institutions, and the private sector. Locations for these activities will be crop-specific. Questionnaires and interviews will be used, and data accessed from all sources including ICRISAT's Geographic Information System unit. The data necessary to assess the impact relate to seed production, sales, distribution and marketing; cropped areas; crop production; and preferences and product acceptability.

A list of relevant contacts can be obtained from scientists working on the respective crops. Areas and crops outside Asia that would require investigation are chickpea in the West Asia and Northern Africa (WANA) region; groundnut throughout Africa; and pigeonpea in eastern and southern Africa, Latin America, and the Caribbean.

Chickpea

For chickpea in Asia, the following varieties and countries/states are to be investigated:

ICCV 1	India (Andhra Pradesh, Maharashtra, Gujarat, Madhya Pradesh) and Nepal (two districts of Nepalganj);
ICCV 2	India (Andhra Pradesh, Maharashtra, Gujarat, Madhya Pradesh) and Myanmar (Magwe, Mandalay, and Sagaing divisions);
ICCV 6	Nepal (two districts of Nepalganj);
ICCV 10	India (Andhra Pradesh, Maharashtra, Gujarat, Madhya Pradesh) and Bangladesh;
ICCV 88202	India (Andhra Pradesh, Maharashtra, Gujarat, Madhya Pradesh);
ICCC 37	India (Andhra Pradesh, Maharashtra, Gujarat, Madhya Pradesh) and Myanmar (Magwe, Mandalay, and Sagaing divisions);
ICCL 82108	Nepal (two districts of Nepalganj).

Pigeonpea

For pigeonpea, the following varieties and countries/regions are to be investigated.

ICP 8863	Central and peninsular India
ICP 9145	Malawi

ICPH 8	Central India
ICPL 87	India, Sri Lanka, Myanmar
ICPL 151	India, Myanmar
ICPL 332	India (Andhra Pradesh)
ICPL 85012	India (Maharashtra)
ICPL 87119	Central and peninsular India

This is a preliminary listing. These eight varieties/hybrids will be subsequently prioritized depending upon the availability of funds for the REIA work program and the time frame within which it must be completed. Such a prioritization is critical for bulk selections but less so for regular seed supplies, for which records are more easily available.

Several intermediate products also need to be assessed for impact:

- ICPX 78120-WR bulk supplied to a research center in Bihar in 1981/82. Selections from this wilt-resistant population have been released and are performing well, according to recent reports;
- Male-sterile sources being used by nine ICAR centers and by seed companies;
- Sources of resistance, widely used by ICAR and other centers.

Groundnut

For groundnut, the varieties and locations for REIA are:

ICGS 11	India (Maharashtra, Andhra Pradesh)
ICGS 44	India (Andhra Pradesh, Tamil Nadu)
ICGS 76	India (Andhra Pradesh, Maharashtra)
ICG (FDRS) 10 and ICGV 86590	India (Andhra Pradesh, Karnataka, Tamil Nadu)
ICGV 86564	India (Andhra Pradesh, high-management conditions)
BARD 699	Pakistan
ICGMS 42	Southern Africa
Rosette-resistant variety	Western Africa

It was also felt that some consideration should be given to the segregating material and breeding lines as intermediate products. The following list was presented (for India):

Resistance to foliar diseases (*A. flavus*, viruses)	Tamil Nadu, Karnataka, Andhra Pradesh, Maharashtra, Gujarat
High yield	Gujarat, Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu
Insect resistance	Karnataka, Tamil Nadu, Andhra Pradesh
Early maturity	Gujarat, Maharashtra, Andhra Pradesh
Screening for water-use efficiency	Tamil Nadu, Andhra Pradesh, Gujarat, Karnataka, Rajasthan, Maharashtra
Screening for bud necrosis virus	Karnataka, Andhra Pradesh, Uttar Pradesh.

Crop and Resource Management

In contrast to the crop improvement programs, crop and resource management research results in the development of techniques and procedures (rather than specific end products), which can then be applied by scientists and farmers. Some of these outputs are listed here, along with REIA objectives and the questions that need to be answered for impact analysis studies. These studies need to consider the nature of such research, where the cause-effect relationship between research outputs and, for example, productivity, is difficult to quantify. Several outputs have been listed. It will be the REIA team's responsibility, in consultation with resource management scientists, to prioritize this list.

Screening methodologies for disease and pest resistance

Several methodologies have been developed, which assist breeders at ICRISAT and elsewhere to incorporate disease and pest resistance into new crop varieties and breeding lines. These have been widely used, especially against downy mildew and the sorghum midge. In order to evaluate their impact, the following information is important:

- Means of transfer to, and degree of use by, NARS scientists;
- Results of use of the techniques in plant breeding programs;
- Results of use of the techniques in resistance screening.

Pest- and disease-resistant source materials and varieties

The objective is to quantify increases in crop yield/stability brought about through the deployment of genetic resistance to major biotic constraints. The following issues need to be covered in this evaluation:

- The effectiveness/stability of resistance on farmers' fields;
- The role of farmers' perceptions of resistance in the acceptance of varieties;
- The extent and the means of spread of these varieties;
- Problems unrelated to resistance.

Strategic research on cropping systems

On-station research on crop/cropping system management (strategic research) has formed a large part of ICRISAT's resource management work; several other programs at ICRISAT have also contributed substantially. The primary objective has been to improve our understanding of the physiology and management of key crop/cropping systems in the semi-arid tropics (SAT). Because this topic is wholly knowledge-based, the questions to be asked during an impact assessment study are:

- How was the knowledge reported/disseminated?
- How and by whom has this knowledge been used?
- What benefits has the research brought to SAT science?
- What benefits has the research brought to SAT farmers?

Because of its nature this component will need to be investigated through literature surveys. It will also be necessary to determine the extent to which farmers have, and use, this knowledge.

Agroclimatology

The Soils and Agroclimatology Division has completed extensive studies on characterization and modeling of the SAT agroclimatic environment. The objective of much of this work has been to provide a sound basis for the design and transfer of suitable agricultural technology throughout the SAT. This transfer has been particularly effective in India and West Africa, where ICRISAT-generated data are major inputs into NARS projections and planning. Since this work, like strategic research on crop systems, is largely knowledge-based, the same questions need to be asked.

On-farm research

In addition to the knowledge-based technologies in a REIA study, two on-farm programs are recommended for the REIA workplan.

Groundnut production technology package. The bulk of this work was carried out by the Legumes On-farm Testing Network (LEGOFTEN) project. The objective was to assemble, demonstrate, and promote an improved technology package to increase groundnut production. Questions to be asked in this evaluation include:

- How did the package as a whole perform?
- To what degree did farmers accept all or part of the package?
- How did farmers modify the package?
- Have these modifications spread to other farmers in the area or to nearby areas?
- What has been the spread of selected components of the package (e.g., raised bed cultivation) to other crops/systems?
- What has been the impact of the package/components on production over time?

Watershed management. This work has been the primary focus of ICRISAT's resource management for some time, and has received considerable publicity. There were two primary objectives (which may have to be evaluated separately): to promote the concept of watershed as a basis for natural resource management and to design and test specific applications for both Alfisol and deep Vertisol areas (in collaboration with NARS). Because of the prominence of this work and its multi-faceted nature, a detailed REIA study is essential. Questions relevant to this evaluation are:

- What has been the influence of the watershed concept on research and development planing?
- To what degree have the concepts been implemented/adopted?
- What has been the effectiveness of ICRISAT's specific package of watershed technology in the two environments, research station and farmers' fields?
- To what extent has the package been adopted by farmers?
- To what extent have the individual components of a package been adopted by farmers?
- What have been the benefits of adopting the package and/or individual components?

A large number of current and former ICRISAT staff have been involved with this work, and their assistance should be sought. Areas where this work was carried out at village level are well documented, and surveys can provide adequate answers.

A number of other outputs from the (former) Resource Management Program can be analyzed for their impact. For example, the groundnut technology packages that have been introduced (through AGLOR) into Myanmar; methodologies for drought/waterlogging resistance screening in pigeonpea; ICRISAT's role in setting up India's *Rhizobium* program; and a large number of intermediate technologies such as diagnostic techniques. These and other outputs can be subsequently assessed, depending on the availability of funds, within an appropriate time-frame.

Socioeconomics and Policy

Two information technologies developed in collaboration with ICRISAT's Socioeconomics and Policy Research Division are presented here for impact assessment:

- Village-level studies;
- Watershed research.

A general observation is that impact analysis of economics research requires economists to evaluate their own work, with the attendant problems of subjectivity and possible biases. The final workplan will be developed in a manner that takes these factors into account.

Village-level studies

Village-level studies (VLS) conducted by ICRISAT from 1975 onwards have generated considerable microeconomic data on Indian households engaged in dryland farming.

The REIA objective is to assess the value of this information. The following methodologies are suggested:

Approach. Comprehensive listing of the outputs and impacts (where possible), grouped by area of research (natural resources, crops, markets, technology development and assessment, income distribution, socioeconomic indicators, etc.) and target of impact (policy, research prioritization, the economics profession, etc.); tracing flows of information; and quantifying the costs of VLS data collection and quantifying values where methods are developed to do so.

Locations. India and West Africa.

Survey instrument. Primarily library work.

Data. Largely secondary data sources; also policy simulations.

Watershed research

This activity represents a major input by ICRISAT economists and deserves to be examined in detail. The objective of such study will be to assess the value of information generated by ICRISAT's research on watersheds. This study will also include LEGOFTEN and CLAN activities both within and outside India.

The approach will be to generate a comprehensive listing of the outputs; quantify impacts and their values; and try to attribute specific values to different actors, i.e., economics researchers, farming systems researchers, etc.

Given the broad scope of this study, suitable locations will be in India (villages 'adopted' by ICRISAT, national watersheds, LEGOFTEN locations), Ethiopia, and Southeast Asia (CLAN locations). To effectively complete this assessment, extensive library work will be needed, followed by village work in all target areas, and interviews with government officials.

Primary and secondary data should be collected from ICRISAT scientists involved with this work, along with collaborating scientists from various disciplines, both within and outside ICRISAT.

Workshop Synthesis

M C S Bantilan[1]

Introduction

Good afternoon, friends. I feel honored to be given the opportunity of presenting to you the workshop synthesis—an overall picture of what transpired during this 3-day workshop.

Workshop objectives

First, let me recapitulate the specific objectives of the workshop:

- To discuss a framework for research evaluation and impact assessment (REIA) that has been developed by economists and crop scientists from various disciplines at ICRISAT;
- To draft a workplan based on this framework;
- To identify the role of participating scientists in the REIA work program.

We discussed the framework for research evaluation; with inputs from scientists, we mapped out a REIA workplan for the next few years, and identified the roles of participating scientists in the workplan. We identified the products/technologies to be tracked by the REIA team, which comprises not just economists, but all ICRISAT scientists.

Workshop design

The workshop was organized in four sessions:

- Products of ICRISAT research. Research outputs were listed; these could be tangible products (e.g., released cultivars or widely used breeding material) or technologies/information (e.g., screening techniques);
- Research evaluation methodology. The framework and principles for analysis were discussed and appropriate impact indicators identified; several case studies were presented;
- Technology identification for impact assessment. Intermediate and final products were identified for impact/constraint analysis, along with the relevant methodologies, locations, survey instruments, and impact parameters for each product;

1. Socioeconomics and Policy Division, ICRISAT Asia Center, Patancheru 502 324, Andhra Pradesh, India.

- Presentation of reports of Working Groups. Four Working Groups were formed: on socioeconomics research and policy, crop and resource management, cereals germplasm enhancement and management, and legumes germplasm enhancement and management. The reports form the basis for the final REIA workplan for the next 5 years.

The workshop design is shown in Figure 1. It served as a template for REIA for each of the crops, research areas, and groups. Figure 1 deals with resource management, but the principles and the various components would be similar for other disciplines. We asked ourselves this question: What are the outputs of our research for the last 20 years? Research output comprises a pool of technology: varieties, hybrids, parental materials, methods, techniques, and information, all coming out of genetic enhancement and crop and resource management research. An important element in the design is also the identification of the clientele who utilize our products—public and private seed sectors, NARS, universities, and farmers.

We identified very clearly the various research outputs, our clientele for each output, and the appropriate methodologies within the REIA framework. We were thus able to identify the product lines for economic assessment in each discipline. We had suggestions on approaches and activities, specific locations, and on which scientists should be involved. Consequently, we have the basis for formulating work schedules and budgets, and commitments of human resources and institutional support.

It is important to clarify our research objectives: past, present, and future. Take for example the breeding and resource management research in groundnut. What were the research objectives for the past 20 years? Do we expect a change in the future? Should ICRISAT's research move upstream? How will this be reflected in our 'product line?

This workshop has focused largely on ICRISAT's work in Asia, but we have also initiated discussions in ICRISAT's regional programs in western/central and southern/eastern Africa. Subsequently, we plan to cover the Latin American region as well. This workshop is the first in a series; follow-up meetings and workshops will address impact assessment issues not taken up here. The issues discussed so far will form the basis of our working plan in the short- and medium terms in Asia, while inputs from subsequent meetings will help us develop a more comprehensive plan to cover other regions (Africa and Latin America).

A research evaluation decision-support system for ICRISAT

Let us view the proposed decision-support system in the context of how the decision-making process works at ICRISAT. The organization as a whole has a clear set of mandates. The scientist must make decisions—e.g., choosing between a number of research options—within the framework of these mandates and on the basis of his or her knowledge, often including a (subjective) opinion of where to apply research resources to maximize impact. Inevitably, biases and pressures are present, and may distort the decision-making process. It is this distortion that the decision-support

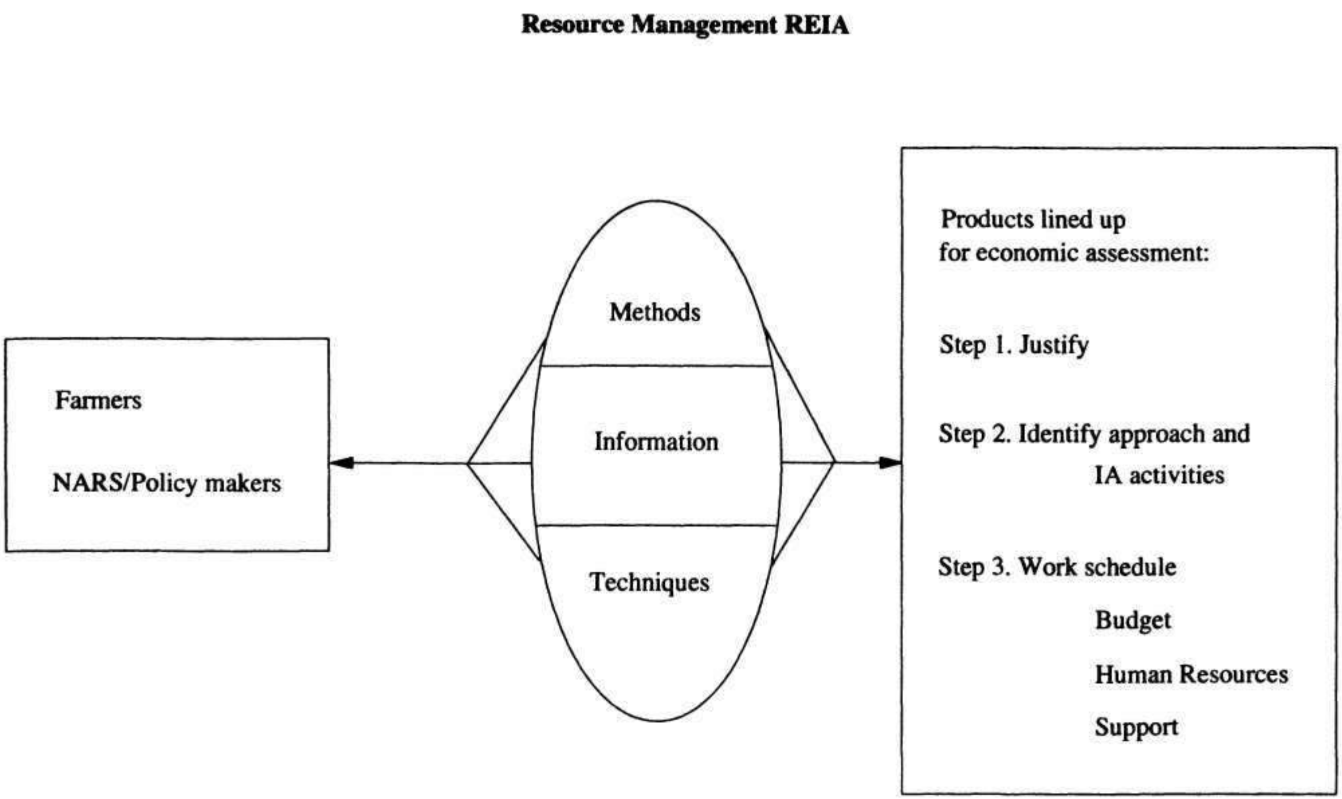

Figure 1. REIA Workshop design.

system seeks to minimize, by providing objective inputs based on which informed decisions can be made. This improved, more systematic system will be built with information elicited from scientists from different disciplines. The designers of this system will combine all the information (both technical and subjective) into an integrated whole.

Once we have such a system, how will it be utilized in ICRISAT? We envisage three broad areas where such a system can be applied:

- To develop new projects by providing qualitative and quantitative information on priorities and opportunities, defined in terms of ICRISAT's comparative advantages;
- To support a review process—information that the system will generate will be comprehensive, and sufficiently rigorous, to be used to review research at various (e.g., project or division) levels;
- To provide continuous and efficient information support for research management. This will be particularly important in view of the recent structural and organizational changes at ICRISAT. This information can be used to strengthen medium- and long-term planning, including planning for collaborative research with NARS and other research institutions.

Strategic vs applied research

ICRISAT's research policy has been to concentrate on areas where we have a comparative advantage, and to focus our work to complement the national programs' efforts in every country in which we work. Since different NARS have different capabilities, ICRISAT's mix of strategic and applied research is not uniform. In western and southern Africa, where NARS are hampered by several constraints, we conduct a lot of applied or adaptive research leading to the development of specific products (e.g., cultivars). In contrast, in India, with its strong NARS and a rapidly growing private seed sector, we are shifting our emphasis to strategic or upstream research. This produces mainly intermediate products—ideas, concepts, methods, techniques, and parent materials—which will be inputs for further research, which in turn will yield products that farmers can use directly.

One feature of strategic research is the possibility of a significant multiplier effect. For example, an ICRISAT intermediate product can be further developed simultaneously by several organizations (e.g., NARS institutes or private/public sector seed companies), with each one developing a product specifically for a particular region or cropping system.

The process of assessing research impact in applied research is not easy. For strategic research, quantifying the value of intermediate products and tracking them as they move through laboratories and research plots into farmers' fields, is even more difficult—but equally essential if a clear picture is to emerge of ICRISAT's research impact.

Conclusions

Four working groups were formed to discuss and identify appropriate technologies and information from ICRISAT to be tracked by the REIA team. Tables 1 and 2 list the varieties/hybrids and specific technologies/information on our mandate crops suggested for the REIA medium-term workplan.

In closing, I would like to emphasize our efforts towards a common purpose. We are all working together. Let this be an integrated workplan, so that economics research will not be only for economists, or entomology research only for entomologists. Impact assessment is for all of us together—only if we stay with this integrated approach can we be sure that our research products will in fact improve the welfare of our ultimate clientele.

Table 1. Varieties/hybrids identified for impact/constraint analysis under the REIA workplan.

Crop	Varieties/hybrids for impact assessment	Varieties/hybrids for constraint analysis
Sorghum	CSH 14 ICSV 745 NTJ 2	ICSV 112 ICSH 153
Pearl millet	ICMH 451 Pusa 23 ICTP 8203 WC-C75 MLBH 104 RCB-IC 911	ICMS 7703 ICMS 423 RCB-IC 9 ICMH 501 HC-4
Chickpea	ICCV 10 ICCC 37 ICCV 2 ICCV 88202 ICCV 1 ICCCL 82108	ICCC 42 ICCV 19 ICCV 88102 ICCV 89230 ICCV 89701 ICCV 89314 ICCV 6
Groundnut	ICGS 44 ICGS 11 ICG(FDRS) 10 ICGS 76 ICGV 86590 ICGV 86564 BARD 699 ICGMS 42	ICG(FDRS)10[1] ICGV 86590 ICGV 86564 ICGS 37
Pigeonpea	ICPL 87119 ICP 8863 ICPL 85012 ICPL 87 ICPL 151 ICP 9145 ICPH 8	ICPL 87[1] ICPH 8 ICPL 332 ICPL 151

1. All groundnut and pigeonpea varieties for constraint analysis are listed for some specific locations. Some of the varieties are included for both impact and constraint analysis.

Table 2. Resource management technologies identified for the REIA workplan.

Research area	Technologies identified
Plant protection	Screening methodologies for disease and pest resistance.
	Impact of pest and disease resistant source materials and varieties.
Agronomy	On-station crop/cropping system management research (strategic research).
Technology packages	Improved groundnut production technology package.
Watershed	Watershed concept of resource management.
Socioeconomics and policy	Information on village level studies.
	Value of the information on watershed technology.
	Grain-fodder value information.
Agroclimatology	Characterization and modeling of the SAT agroclimatic environment.

Concluding Remarks

Y L Nene[1]

Thank you, Dr Bantilan, for that excellent synthesis of the workshop discussions. I would like to say at the outset that we had an excellent meeting, during the course of which we—and I think I can speak for all of us—have been well sensitized to the impact assessment issue.

This is all the more important because this issue was also considered important by ICRISAT's External Program Review (EPR) panel. I feel it would be worthwhile to quote three passages from our last EPR panel report (1990).

> The panels rated ICRISAT's impact as very satisfactory, and are confident that several of ICRISAT's technologies hold great promise for the future. Progress has been most rapid in India, and the impact on production has been particularly important for pearl millet and groundnuts. Nothing 'spectacular' is visible yet for the other mandate crops or in areas outside India ... We do hope that by [the time of the next EPR] ICRISAT would have collected more quantitative evidence on the impact of its activities than it was able to share with these panels. The panels were also not always clear how much value ICRISAT had added, e.g., in the transfer of germplasm ...
>
> With a mandate region as wide as the semi-arid tropics and with five mandate crops, impact assessment is no easy task. Every month, perhaps two or three varieties based on ICRISAT-bred materials are released somewhere in the world. By the very nature of international agriculture research, it is difficult, if not impossible to estimate the share of the credit that ought to be given to ICRISAT and to collaborating institutions which adopt the materials to local conditions or provide basic material. Can one really make a causal link between the activity of one actor in the global agricultural research system, and global indicators of yield, production of income level, production, or income levels? Impact is dependent on so many factors, including the strength of national programs, good government policies, and the availability of inputs. Is it really worthwhile for ICRISAT to make the effort? We say yes. Surely the Center must be able to do better than to quote a series of statistics from the FAO Production Yearbook, or to point to the number of varieties based on ICRISAT materials that have been released.'

This clearly indicates the challenge we face to document the impact of our research, and also the panel's dissatisfaction with what we have done so far on impact assessment.

1. Deputy Director General, ICRISAT, Patancheru 502 324, Andhra Pradesh, India.

The panels believe that ICRISAT should commission an *ex post* evaluation of the impact of a *sample of its activities* [italics added]. This study should also look at the reasons for adoption or rejection of ICRISAT technology, and the implications for future research. Such a study should systematically collect information from seed production companies and extension agents, and carry out field surveys at selected locations. It should also make an estimate of the value that had been added to the technology under consideration through ICRISAT's activities. The results will not only be of major benefit to the formulation of ICRISAT's future priorities, but will also be greatly welcomed by donors. Impact assessment should become an integral part of project formulation; each research project should contain a statement as to the likely impact that will result from the project.'

I will quote another passage, this time from the Technical Advisory Committee (TAC) commentary on the EPR report.

> 'TAC is encouraged by the ICRISAT's records of achievement and the emerging evidence of the Center's impact. The committee notes that available information on ICRISAT's impact is to a large extent beneficial, and concurs with the panel that ICRISAT should commission a study on *ex post* evaluation of the impact of a sample of its activities.'

This brings out several things we have talked about during these three days, and at the same time reminds us that we have a clear task ahead of us. The date for the next EPR is not yet fixed, but in all probability it would be in 1996. We have another 2 $^{1}/_{2}$ years or so within which the expected task is to be done. Dr Ryan, soon after he joined ICRISAT, laid great emphasis on this particular aspect, and people in ICRISAT know what has been done on impact assessment. The very appointment of Dr Bantilan, and the tasks she has accomplished since she joined the Institute, clearly indicate that we are focused on what we are expected to do. This is very reassuring.

I have always had a problem with the word 'impact'. Webster's dictionary (having been trained in the USA, I tend to believe Webster more than others) defines it as 'the act of impinging or striking ... a forceful contact or collision'. But when we talk about impact, we are not implying any of these things. I recollect having had a discussion some days earlier on the impact of Indian NARS on the CGIAR centers. The next time I meet Dr Chopra (Director General of the Indian Council for Agricultural Research and Vice Chairman of ICRISAT's Governing Board) and officials from other NARS, I am going to request them to commission a study of impact of the national programs on the CGIAR system as a whole. I am sure India can produce a voluminous report on what India has contributed to the CGIAR system. The reason I am making this point is that impact assessment is essentially collaborative; this has been clearly brought out during this meeting. The choice of the word 'impact' is unfortunate. I would have preferred 'achievements' or 'contributions', but we will have to live with 'impact'. I am sure our partners from other institutions realize that when we talk of impact, it is not a forcible thrust, but achievements and contributions achieved together and for mutual benefit.

I am wary about statements made by my colleagues that ICRISAT must now move towards more strategic research. Somehow, an impression is created that we are moving away from adaptive research, almost as if adaptive research is somehow less satisfying, or less fashionable, than strategic research. But let me remind you that currently, 40% of our research is basic and strategic; the remaining 60% is applied and adaptive research. What we are suggesting in our strategic plan is only a shift—not a fundamental policy change—to a 60:40 ratio of strategic: adaptive research by the end of 1998. Our previous Director General, Dr Swindale, in his last mid-term CGIAR meeting in Paris, had made it very clear that if the IARCs are to create an impact, then they must be allowed to conduct applied and adaptive research. I just wanted to share this thought with my colleagues; please do not consider that applied and adaptive research is going out of fashion, or will be valued less in ICRISAT than strategic and basic research.

At one stage during this meeting, when I saw a long list of what we should be doing, and heard suggestions from the participants as to what *else* should be done, I felt as if I were in a giant supermarket, wanting to buy everything in sight—with only $100 in my pocket. But when I heard Drs Byth, Kelley, and Bantilan, I felt a lot easier in my mind. I agree entirely with them that it is impossible to do everything. We have to prioritize; we have to choose where best information can be obtained; even the EPR report says 'a sample of activities'. It does not recommend impact assessment of the Institute's every activity. We have many achievements to our credit, and certainly we will have sufficient evidence of impact, at least for the more important achievements.

On behalf of the Director General, and on the Institute's behalf, I wish to thank the distinguished guest participants from other institutions who accepted our invitation, gave us so much of their time, and made very valuable suggestions. I must also thank all my colleagues at ICRISAT for having extended their cooperation to this effort; and I am saying this on behalf of Dr Bantilan and the rest of the group who organized this workshop.

Participants

O P Govila
Project Coordinator
All India Coordinated Pearl Millet
Improvement Project (AICPMIP)
Division of Genetics
Indian Agricultural Research Institute
New Delhi 110 012

V Jaya Mohan Rao
Chief Scientist
A P State Seeds Development
Corporation Ltd
HACA Bhavan
Saifabad
Hyderabad 500 004

D Jha
Principal Scientist
National Centre for Agricultural
Economics and Policy Research
Library Avenue, Pusa Complex
New Delhi 110 012

J C Kalla
Joint Director
National Academy for Agricultural
Research Management
Rajendranagar
Hyderabad 500 030

U R Murthy
Director
National Research Centre for Sorghum
Rajendranagar
Hyderabad 500 030

Suresh Pal
Scientist
Division of Agricultural Economics
Indian Agricultural Research Institute
New Delhi 110 012

H D Patil
Station Manager
ProAgro Seed Company Ltd
Plot No. 176, N-3 CIDCO
New Aurangabad 431 005
Maharashtra

K E Prasada Rao
Vikki's Agrotech Ltd
Plot no. 18, Road no. 3
Banjara Hills
Hyderabad 500 034

G S Ram
Economic Adviser
Directorate of Economics and Statistics
Krishi Bhavan
New Delhi 110 001

K V Ramaiah
Krishi Nagar
ICRISAT Colony - Phase II
Hashmathpet Road
Secunderabad 500 011

K P C Rao
Senior Scientist
National Academy for Agricultural
Research Management
Rajendranagar
Hyderabad 500 030

M Satyanarayana
Indo-Swiss Project
Veterinary Biological and Research
Institute
10-2-282 Shanti Nagar
Hyderabad 500 028

Raman Kumar Sehgal
President
ProAgro Seed Company Ltd
8-139, Toli Chowki
Hyderabad 500 008

R P Singh
Director - Economics
National Institute of Rural Development
Rajendranagar
Hyderabad 500 030

ICRISAT
Patancheru 502 324, Andhra Pradesh, India

J G Ryan, Director General
Y L Nene, Deputy Director General
D E Byth, Associate Director General, Research
J S Kanwar, Deputy Director General (Emeritus)
K Harmsen, Executive Director, Western and Central Africa Region Program

Agronomy Division
M M Anders, Principal Scientist
F R Bidinger, Principal Scientist
D J Flower, Principal Scientist
C Johansen, Principal Scientist and Research Director
M V Potdar, Scientist

Cereals and Legumes Asia Network
C L L Gowda, Principal Coordinator

Crop Protection Division
F T Bantilan, Senior Scientist
D McDonald, Principal Scientist and Research Director
K F Nwanze, Principal Scientist
C S Pawar, Scientist

Farm and Engineering Services Program
D S Bisht, Program Leader

Genetic Enhancement Division
R P Ariyanayagam, Principal Scientist
C T Hash Jr, Principal Scientist and Crop Coordinator, Pearl Millet
K C Jain, Senior Scientist
S N Nigam, Principal Scientist and Crop Coordinator, Groundnut
Eva W Rattunde, Scientist
H W Frederick Rattunde, Scientist
Belum V S Reddy, Senior Scientist
L J Reddy, Senior Scientist
K B Saxena, Senior Scientist
S C Sethi, Senior Scientist
J W Stenhouse, Principal Scientist and Crop Coordinator, Sorghum
B S Talukdar, Scientist
H A van Rheenen, Principal Scientist and Crop Coordinator, Chickpea

Genetic Resources Division
S Appa Rao, Senior Scientist
M H Mengesha, Principal Scientist and Research Director

Information Management and Exchange Program
Ajay Varadachary, Editor

Socioeconomics and Policy Division
K V Anupama, Research Associate,
M Asokan, Senior Research Associate
M C S Bantilan, Principal Scientist
V K Chopde, Research Associate
K R Chung, Scientist
R Hari Haran, Research Associate
P K Joshi, Senior Scientist
T G Kelley, Principal Scientist
J M Kerr, Scientist

V B Ladole, Research Associate
Y Mohan Rao, Senior Research Associate
G D Nageshwar Rao, Research Associate
P Parthasarathy Rao, Senior Research Associate
P S S Raju, Research Associate
K P Ch S Raju, Junior Secretary
Ramadevi Koli, Scientist
K V Subba Rao, Senior Research Associate
Ch Vijaya Kumar, Data Processing Assistant
Meri L Whitaker, Scientist

Soils and Agroclimatology Division

N K Awadhwal, Senior Scientist
Prabhakar Pathak, Senior Scientist
T J Rego, Senior Scientist
K L Srivastava, Senior Scientist
S M Virmani, Principal Scientist
S Lalitha, Research Associate

About ICRISAT

The semi-arid tropics (SAT) encompasses parts of 48 developing countries including most of India, parts of southeast Asia, a swathe across sub-Saharan Africa, much of southern and eastern Africa, and parts of Latin America. Many of these countries are among the poorest in the world. Approximately one sixth of the world's population lives in the SAT, which is typified by unpredictable weather, limited and erratic rainfall, and nutrient-poor soils.

ICRISAT'S mandate crops are sorghum, pearl millet, finger millet, chickpea, pigeonpea, and groundnut; these six crops are vital to life for the ever-increasing populations of the semi-arid tropics. ICRISAT'S mission is to conduct research which can lead to enhanced sustainable production of these crops and to improved management of the limited natural resources of the SAT. ICRISAT communicates information on technologies as they are developed through workshops, networks, training, library services, and publishing.

ICRISAT was established in 1972. It is one of 18 nonprofit, research and training centers funded through the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is an informal association of approximately 50 public and private sector donors; it is co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), the World Bank, and the United Nations Development Programme (UNDP).

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

ISBN 92-9066-302-2 Order code: CPE 091 Printed at ICRISAT Asia Center 193-94