Generations of Research for the Semi-Arid Tropics from ICRISAT/NARS Partnerships

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Managing germplasm and research on genetic enhancement that leads to the delivery of improved final products is a complex process involving multiple steps. These include assembly and characterization of germplasm, population improvement, pedigree development, in-breeding, agronomic research, on-station and on-farm trials, demonstrations, seed multiplication, certification, quality control, distribution, and dissemination. Each step in the process involves partnerships among international agricultural research centers (IARCs), national agricultural research systems (NARS), the seed sector, and the extension network. Figure 1 is a schematic representation of the research, development, and dissemination process over time, indicating the roles of various players.

This paper provides background on the joint achievements of ICRISAT and its NARS partners in germplasm improvement research. The various research [illegible] over the years in response to changes in the research environment, and provides a summary of the range of intermediate and final products derived from research on sorghum, millets, chickpea, pigeonpea, and groundnut, and presents an analysis of research time lines for the range of research products.

Objectives

The ICRISAT/NARS 'research product mix' reflects targets that have evolved continuously in response to changing internal and external research environments. During their inception in the early 1970s, ICRISAT crop improvement programs were established with these objectives:

- Emphasis on applied, rather than basic research;
- Genetic enhancement for yield, disease, and insect pest resistance, and drought tolerance;
- Emphasis on the development of both finished products (cultivars) and improved intermediate products (breeding materials and parental lines); and
- Development of improved breeding methodologies and screening techniques as an integral part of applied research.

Early research efforts focused on finished products, so that most investments were directed toward breeding for improved resistance sources and high-yielding populations, and to developing efficient screening techniques, varieties and hybrids, and recommendations for improved crop management. [illegible] capabilities and private [illegible] developed, ICRISAT gradually shifted its emphasis toward strategic research areas where it enjoys comparative advantage. Over the years, the research focus shifted from finished products to improvement of the germplasm management program and development of genetically enhanced, advanced breeding lines and populations from which NARS collaborators could select materials best suited to local conditions. Emphasis is also given to the improvement of ICRISAT's germplasm management program.

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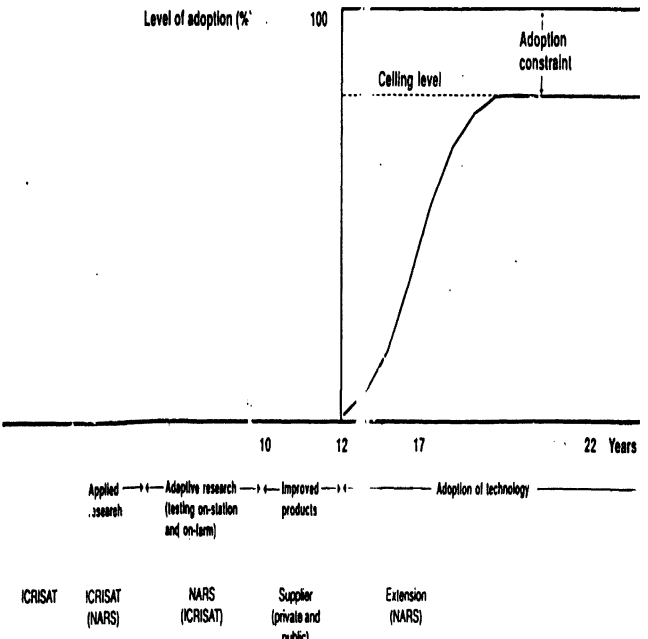

Figure 1. Representation of the research, development, and adoption proce[illegible]r time, indicating relative involvement of ICRISAT and national agricultural research systems (NARS).

New objectives included:

- Conserving genetic diversity;
- Distributing genetic material to NARS worldwide;
- Developing specific new gene pools and novel plant types;
- Breeding resistant seed parents and restorer lines;
- Further refining breeding and screening methodologies, including the application of biotechnology to identify and use molecular markers in breeding; and
- Understanding new crop mechanisms and their genetics.

Breeding materials, including elite germplasm, segregating populations, and advanced breeding lines, are supplied to national programs on request, as is material for international varietal trials.

Research products

The ICRISAT/NARS partnership has produced a range of research products. The following descriptions incorporate data presented in Bantilan and Joshi (1994), drawing from contributions of a team of scientists who provided detailed information of ICRISAT/NARS intermediate and final product (Manyong et al., Rao 1994, Reddy and Stenhouse 1994, Rai and Hash 1994, Reddy and Nigam 1994, Sethi and van Rheenan 1994, Ariyanayagam and Jain 1994).

Table 1 lists a range of intermediate and final products from germplasm management and genetic enhancement research, including products from ICRISAT's germplasm accessions, selections for sources of resistance, segregating populations, screening techniques, early and advanced generation progenies, and released varieties and hybrids.

This initial inventory of research products provides an important starting point to assess the joint impact of the ICRISAT/NARS partnerships. Starting with this first inventory, updates will reflect a comprehensive set of mutually beneficial achievements and contributions from ICRISAT and NARS. The ultimate aim is to feature important benefits from germplasm management and genetic enhancement research including:

- Conservation of genetic diversity;
- Evaluation and characterization that facilitates the use of germplasm for crop improvement;
- Distribution of genetic materials to NARS worldwide;
- Higher productivity from improved cultivars.

Table 1. Range of ICRISAT/NARS final and intermediate products based on scientist inventory, as of 1993.

Research products	Sorghum	Pearl millet and minor millets	Chickpea	Pigeonpea	Groundnut	Total
Genebank accessions	33766	32861	16878	12393	13949	109847
Germplasm accessions and selections released	21	2	9	13	7	52
Germplasm samples to NARS	237265	126717	99048	51507	70142	584679
Cultivar releases developed at ICRISAT	12	23	4	15	15	69
NARS releases using ICRISAT materials	21	11	19	5	7	63

- Cost reductions and yield gains from insect and disease resistance and drought tolerance;
- Improved breeding efficiency resulting from better screening technologies, breeding methods, and concepts; and new information on genetics and resistance mechanisms;
- Improved product quality; and
- Strengthened NARS capabilities.

Research time lines

Time lines identify the time spent during various research phases from start to product release. Analysis of these phases is interesting because it provides an historical perspective of the research effort. More importantly, it reveals relative research strengths among research actors, as well as where constraints may occur during the R&D process. It also indicates varying degrees of institutional support to development, dissemination, and availability of research products.

Table 2 presents data on the R&D time lines for sorghum cultivars released by various NARS from 1983 to 1994, including research time lags (the period from research start to product identification) and release time lags (number of years from product identification to varietal release). The table covers those varieties or hybrids developed by NARS us[illegible] ICRISAT materials.

NARS sorghum programs spent an average of 5 years (averaged across all regions) to identify a cultivar. Variation in research time lags across countries, however, is large. For example, it took 4 years in Ethiopia and Malawi, 5 years in China and Mexico, 4 to 7 years in India; and 6 to 9 years in Niger. These wide ranging time lags indicate not only variation in the adaptability of parent materials, but also relative research strengths of the various breeding programs across

Table 2. Research time lines for sorghum varieties and hybrids developed by NARS using parental materials from ICRISAT.

Cultivar	Research started	Product identified	Product released		Research time lag	Release time lag	Total time lag
			year	Country			
[illegible]	[illegible]	1982	1993		[illegible]		17
[illegible]	1977	1986	1993	Niger	9	7	16
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HD 1	1978	1980	1983	Sudan	2	3	5
ICSV 1	1976	1980	1989	Malawi	4	9	13
Melkamesh	1976	1980	1986	Ethiopia	4	6	10
ICSH 110	1976	1983	1988	India	7	5	12
ICSV 197	1979	1983	1986	India	4	3	7
CSH 14	1981	1985	1993	India	4	8	12
ICSV 745	1983	1989	1993	India	6	4	10
MLSH 36	1985	1990	1994	India	5	4	9
PKH 400	1985	1990	1993	India	5	3	8
PSH 8340	1985	1990	1993	India	5	3	8
PJH 55	1985	1990	1993	India	5	3	8
PJH 58	1985	1990	1993	India	5	3	8
JKSH 22	1985	1990	1993	India	5	3	8
JKSH 27	1985	1990	1993	India	5	3	8
NTJ 2	1985	1989	1990	India	4	1	5
Liao 4	1981	1986	1988	China	5	2	7
Tropical 401	1985	1990	1991	Mexico	5	1	6

regions. Differences are also noted within regions — time lags are significantly shorter in eastern Africa (e.g., Ethiopia and Malawi) than in western Africa (e.g., Niger).

Release time lags ranged from 1 to 11 years — 1 to 2 years in China and Mexico, an average of 3.5 years in India, 5.8 years in Ethiopia, Malawi, and Sudan, and an average of 9 years in Niger. When both types of time lags are considered, it took almost twice as long to deliver an improved cultivar to farmers in Niger and Malawi (an average of 15.3 years) than in China, Mexico, and India (an average of 8 years). These time lags indicate relative institutional strengths among extension networks in delivering improved materials to farmers, variations in institutional support by governments, and corresponding demand for improved cultivars in these regions. Table 2 also shows that an early policy shift by the ICRISAT sorghum program to focus on development of parental lines significantly increased cultivar releases in the early 1990s in India based on ICRISAT parent materials.

The data presented for pearl millet (Table 3) include information on research and release time lags for open-pollinated varieties and hybrids bred at ICRISAT Patancheru and released in India, Namibia, and Zambia. On average, the total time lag for open-pollinated varieties is 9 years — 4 years from research initiation to product identification and 5 years for product release. Hybrids took an additional 2 years. Adaptive research and release of open-pollinated varieties by NARS outside India was quite rapid — ICMV 88908 was released in 1990 as Okashana 1 in Namibia (replacing ICTP 8203 that was pre-released in 1989 under the same name). ICMV 82132 was released in 1989 as Kaufela in Zambia, and WC-C75 was released as ZPM 871 in 1987 in Zambia.

Table 3. Research time lines for pearl millet varieties and hybrids bred at ICRISAT-Patancheru and released in India.

	Cultivar	Research started	Product identified	Product released	Research time lag	Release time lag	Total time lag
	ICMH 356	1981	1988	1993	7	5	12
	ICMH 451	1975	1981	1986	6	5	11
	ICMH 501	1978	1981	1986	3	5	8
Varietie	ICMV 155	1978	1985	1991	7	6	13
	WC-C75[1]	1971	1976	1982[1]	5	6	11
	ICMS 7703	1974	1977	1985	3	8	11
	ICMV 82132[2]	1979	1982	1989[2]	3	7	10
	ICMV 221	1985	1988	1993	3	5	8
	ICTP 8203[3]	1981	1983	1988[3]	2	5	7
	ICMV 88908[4]	1985	1988	1990[4]	3	2	5

1. Released as ZPM 871 in Zambia in 1987
2. Released as Kaufela in Zambia in 1989.
3. Popular as Okashana 1 in Namibia
4. Released as Okashana 1 in Namibia in 1990.

Research and release time lags were relatively long for chickpea and groundnut varietal improvement. Chickpea varietal improvement took almost 15 years in some countries, including India, Nepal, Bangladesh, Ethiopia, and Kenya. The data for India show that it takes an average of 12 years to develop and identify a chickpea variety before it can be recommended for release. However, once a product is identified, the system ensures fairly rapid release (Table 4).

For groundnut cultivars, except for the natural hybrid derivatives from Kadiri 3, it has taken about 8 years from research start to product identification (Table 5). Release time for groundnut varieties improved over the last few years — before 1990, it took 4 – 9 years to release a cultivar after it was identified, however, more recent releases (e.g., ICGV 86590 and ICGV 86325) were greatly aided by policy and institutional changes.

Table 4. Research time lines for released chickpea varieties bred from parental materials developed at ICRISAT.

Country	Cultivar	Research started	Product identified	Product released	Research time lag	Release time lag	Total time lag
India	ICCV 10	1975	1992	1993	17	1	18
	ICCC 37	1974	1988	1989	14	1	15
	ICCV 2	1975	1984	1989	9	5	14
	ICCV 1	1973	1982	1983	9	1	10
Bangladesh	Barichola 3	1974	n a[1]	1993			19
	Barichola 2	1975	n a	1993			18
	Nabin	1974	n a	1986			12
Nepal	Kosheli	1973	n a	1990			17
	Sita	1973	n a	1987			14
	Kalika	1976	n a	1990			14
Ethiopia	Mariye	1974	n a	1988			14
Kenya	ICCL 83110	1974	n a	1986			12

1. n a = data not available.

Table 5. Groundnut varieties developed by ICRISAT released in India.

Cultivar	Research started	Product identified	Product released	Research time lag	Release time lag	Total time lag
ICGS 11[1]	1977	1980/81	1986	4	5	9
ICGS 44[1]	1977	1982/83	1988	6	5	11
ICGS 37[1] (ICGV 87187)	1977/78	1980/81	1990	4	9	13
ICGS 1[1] (ICGV 87119)	1977/78	1981	1990	4	9	13
ICGS 76 (ICGV 87141)	1977/78	1985	1989	8	4	12
ICG(FDRS) 10 (ICGV 87160)	1978	1983	1990	5	7	12
ICGV 86590	1979	1988	1991	9	3	12
ICGV 86325	1980	1989	1994	9	5	14

1. Natural hybrid derivative from Kadiri 3.

Conclusions

The ICRISAT/NARS partnership in germplasm improvement research offers these implications for research evaluation:

- There is an effective relay of intermediate and/or final products from ICRISAT to NARS worldwide.
- Given the considerable number of materials awaiting identification and/or subsequent release, a marginal reduction in the research and release time lags will substantially increase the number of cultivars available to farmers.
- Intra-regional differences in research time lags reflect differences in relative 'difficulty' across various constraints. A problem may be more easily solved in one part of a region than in another.
- There is considerable scope for reducing the total time lag through improved institutional efficiency when releasing improved materials.
- Computation of research benefits should take into account the large disparities in relative research strengths across regions and the large variation in research time lags across regions and commodities.
- Impact or ex-ante assessment of research investment has become a critical factor in setting priorities and allocating resources. To facilitate the conduct of both ex-post and ex-ante impact assessment, it is essential to understand that the generation of research products involves varying research environments and relative strengths across the whole research–extension–adoption continuum.

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