As part of the overall CGIAR 2005 annual performance measurement exercise, the Science Council received 30 individual case studies of Center impact. These were the best examples of impact assessments done by the Centers during 2003–2005. The Science Council's Standing Panel on Impact Assessment (SPIA) identified six of these as being particularly meritorious in terms of quality of analysis and presentation. In recognition of these studies as good examples of emerging 'best practice', SPIA has, with the relevant Center's concurrence, prepared Science Council/SPIA Briefs on each. Publishing quality impact briefs responds to continued calls from donors to the CGIAR for more documented evidence of impacts to be made available in the form of such concise publications.

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Spillover Increases Returns to Sorghum Genetic Enhancement

Spillovers across country borders and environments are an important determinant of the returns to investment in research to develop new crop cultivars. It has often been argued that, in heterogeneous environments, these returns will be low because new cultivars will tend to be location-specific.

This brief reports on the findings of a study that refutes this argument, demonstrating that, on the contrary, cultivars originating from collaborative national and international research can prove highly transferable across different environments. The study concerned the spillover effects of research on the genetic enhancement of sorghum, a food and forage cereal widely grown and consumed by poor people across the world's semi-arid tropics. It was conducted by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), based at Patancheru in Andhra Pradesh, India, in collaboration with national program partners in Asia and sub-Saharan Africa.[1]

Data and methodology

The study drew on data from three sources: the International Sorghum Varietal and Hybrid Adaptation Trial (ISVHAT), coordinated by ICRISAT; the All-India Coordinated Sorghum Improvement Project (AICSIP), managed by India's national sorghum breeding program; and national survey data, obtained through ICRISAT's Impact Monitoring Survey. The ISVHAT data covered the period 1989–92, during which experiments were conducted at 59 locations in 26 countries of Asia, Africa, and Latin America. The AICSIP data spanned 1975/76 to 1995/96, when sorghum cultivars were tested at some 67 locations in India. The national survey data were obtained by sending a questionnaire on the release of new cultivars to major sorghum-producing countries across the semi-arid tropics.

The scientists conducting the study used an econometric model to assess the spillover potential of sorghum varieties and hybrids across eight Sorghum Research Domains (SRDs). Originally defined by ICRISAT in the early 1990s and since used as an important tool in collaborative sorghum research, SRDs are defined as homogeneous ecoregions, sharing similar uses of sorghum in addition to soils and climatic conditions that may extend across national boundaries. The eight domains are:

- Widely adapted sorghum (SRD1)
- Dual-purpose sorghum with specific adaptation (SRD2)
- Dual-purpose sorghum with fodder emphasis (SRD3)
- Forage sorghum (SRD4)
- Early-sown postrainy-season sorghum (SRD5)
- Late-sown postrainy-season sorghum (SRD6)
- Irrigated sorghum (SRD7)
- High-altitude (SRD8.1) and/or high-latitude sorghum (SRD8.2).

Successful breeding strategy

Analysis of the ISVHAT data for cultivars developed solely by national programs generally confirmed the hypothesis that cultivars developed in a given SRD perform better there than do cultivars developed in other SRDs. These findings suggest that the SRDs defined by ICRISAT reflect genuine environmental and usage differences that should affect breeders' selection criteria.

This was not the case, however, for cultivars developed at the international level. In contrast to purely national cultivars, those developed by ICRISAT performed well across a wide range of SRDs. For example, cultivars bred at Patancheru, in the wide adaptatability SRD1, had grain yield advantages of 354 kg/ha in SRD3 and 175 kg/ha in SRD2, the two dual-purpose domains. As well as the high potential for spillover, these findings indicate that ICRISAT's strategy of breeding for wide adaptability has been highly successful.

ICRISAT-bred cultivars had higher grain yields than cultivars bred for specific domains across all domains except the irrigated (SRD7) and the high-altitude (SRD8.1) domains. The reason for these exceptions is that these environments differ markedly from the others. Even so, varieties bred for irrigated conditions (SRD7) outperformed national cultivars bred for both the dual-purpose domains in their 'home' domains (SRD2 and SRD3).

The only exception to the broad adaptability of ICRISAT-bred cultivars lies in SRD8, the high-altitude/high-latitude domain. Climatic conditions in this domain, typified by western China, are entirely different from those of other domains. This implies that the best way ICRISAT can assist China's national program is by providing intermediate (enhanced germplasm materials), rather than finished products (varieties or hybrids). ICRISAT began moving in this direction in 1990, since when several derivatives of ICRISAT-bred lines have contributed to the Chinese national program.

A major limitation of the ISVHAT is that it does not provide data on forage (stalk) yields. This means that the results for the dual-purpose and forage domains (SRDs 2, 3, and 4) are of limited value, since lower grain yields for human consumption here represent a trade-off against forage supplies for livestock.

Table 1 presents the spillover matrix developed for selected cultivars included in the ISVHAT. For each domain, the matrix shows the percentage gain or loss in yields that can be expected by moving a cultivar away from the domain in which it was developed.

Analysis of the AICSIP trial data for Indian locations gave similar results. National program cultivars developed in the wide-adaptability domain (SRD1) did well in most other domains, indicating India's successful collaboration with ICRISAT to develop cultivars with a high potential for spillover. Purely national varieties developed in other domains generally did less well when transferred outside their domain. ICRISAT-derived cultivars again showed yield advantages across a wide range of environments.

Regression analysis of both data sets confirmed the wide adaptability and transferability of cultivars bred by

Table 1.
Estimated spillover matrix for selected ISVHAT cultivars

Original domain of cultivar	Domains where cultivars were tested						
	SRD1	SRD2	SRD3	SRD4	SRD7	SRD8.1	SRD8.2
SRD1	1.00	0.95	0.84	1.50	0.73	0.36	1.16
SRD2	0.96	1.00	0.87	1.88	0.78	0.23	1.28
SRD3	0.88	1.05	1.00	1.68	0.85	0.42	1.21
SRD4				1.00			
SRD7	0.80	1.13	0.80	1.28	1.00		
SRD8.1						1.00	
SRD8.2							1.00
ICRISAT–Patancheru	1.15	1.13	1.07	2.17	0.83	0.33	1.27

Source: Deb et al. (2004).[2]

ICRISAT-Patancheru and its Indian and other national partners. This points to the success of this collaborative research in reducing genotype × environment (G×E) interactions and developing widely adapted cultivars, especially across the rainfed areas and at low to moderate altitudes.

Data from the survey of national programs showed that spillover has actually occurred in many sorghum-growing countries of Asia and Africa. For example, Macia, a variety released in Mozambique, was later also released in Botswana, Namibia, and Tanzania. Similarly, S 35, a variety developed in India, has been released in Cameroon and Chad, where it has been widely adopted by farmers. Also of Indian origin is the variety ICSV 111, which has been released in Burkina Faso, Chad, and Nigeria. Seredo, developed in Uganda, is now grown by farmers in Ethiopia, Kenya, and Tanzania. These examples confirm that plant breeders in both regions have indeed generated technology with wide adaptability and hence potential for spillover.

To identify the human factors responsible for actual spillovers, the strength of national programs was assessed in terms of the number of scientists and their educational level. Paradoxically, it was found that more cultivars from ICRISAT-supplied materials were released in countries with limited research capability than in countries with strong national programs, which tended to use ICRISAT-bred lines as parents to develop their own materials. The major exception was India, where strategic research was undertaken by ICRISAT in collaboration with the national program.

High transferability

It has often been assumed that location-specificity will constrain the spread of improved technology in the heterogeneous rainfed production systems of Asia and Africa. The results of this study refute this assumption.

The study showed that sorghum cultivars originating from collaborative international and national research are highly transferable across different environments and countries. Cultivars developed internationally for wide adaptability generally performed better than those bred for local adaptation by national programs.

This scenario holds good for sorghum varieties developed in India. Here the potential for technologies developed for wide applicability by the national program in collaboration with ICRISAT do indeed have high potential to spill over to other environments.

The only major qualification that needs to be made with regard to these results relates to environments where livestock are important. Here more data are needed on stalk yield (used as fodder for livestock) to complement the data on grain yield (for human consumption), before wide adaptability can be confirmed.

The spillover of finished products tended to be negatively correlated with national research capability: the stronger the national program, the lower the potential for the direct release of varieties and hybrids, since such programs tend to use ICRISAT-bred lines as parents. Accordingly, ICRISAT, like other international centers, is pursuing separate breeding strategies for strong and weak national programs. It should continue with strategic research to produce intermediate products for the former, while engaging in partnerships with the latter to help them develop finished products.

Notes

1 The full version of the study on which this brief is based is: Batilan M.C.S, Deb U.K., Gowda C.L.L., Reddy B.V.S., Obilana A.B., and Evenson R.E. (Eds). 2004. *Sorghum Genetic Enhancement: Research Process, Dissemination, and Impacts*. International Crops Research Institute for the Semi-Arid Tropics: Patacheru, India. The study is available at http://impact.cgiar.org/

2 Deb U.K., Bantilan M.C.S., Bantilan F.T., and Gowda C.L.L. 2004. Spillover impacts of sorghum research, pp. 237–260 In: *Sorghum Genetic Enhancement: Research Process, Dissemination, and Impacts* (Bantilan M.C.S., Deb U.K., Gowda C.L.L., Reddy B.V.S., Obilana A.B., and Evenson R.E., Eds). International Crops Research Institute for the Semi-Arid Tropics: Patancheru, India.

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