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Impact of Germplasm Research Spillovers

THE CASE OF SORGHUM VARIETY S 35 IN CAMEROON AND CHAD

International Crops Research Institute for the Semi-Arid Tropics

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Abstract

An important objective of international agricultural research institutions is to determine the extent to which research undertaken in one location may impact on other regions of interest. This is because research activities are most often planned to target mandate crops and agroecological areas found in many parts of the world. ICRISAT has, as a policy, distributed a wide range of parental materials to breeding programs in the NARS and private seed industries throughout the semi-arid tropics. This has contributed to faster and cost-effective development of useful final products by the receiving parties.

This study evaluates the impacts and research spillover effects of adoption of sorghum variety S 35, a pure line developed from the ICRISAT breeding program in India. It was later advanced in Nigeria and promoted and released in Cameroon in 1986 and Chad in 1989. Today, S 35 occupies about 33% of the total rainfed sorghum area in Cameroon and 27% in Chad. Compared to farmers' best traditional varieties across all study sites in Cameroon and Chad, S 35 yields 27% more output (grain) and reduces unit production cost by 20%.These farm-level impacts are larger in Chad where yield gain is 51% higher and cost reduction is 33% higher. The net present value of benefits from S 35 research spillover in the African region was estimated to be US$ 15 million in Chad and US$ 4.6 million in Cameroon, representing internal rates of return of 95% in Chad and 75% in Cameroon. These impacts were evaluated from the perspective of national research systems. A conscious decision, therefore, was made to include only those costs associated with national research and extension institutions. All other S 35-related research and development expenditures incurred in India and Nigeria were treated as 'sunk costs', that is, costs which would have occurred anyway without spillover. Had each country had to develop S 35 and associated management practices on its own, the time lag between research and release of the technology would have been longer and consequently impacts, if any, would have been smaller. For greater effectiveness in sorghum technology development and transfer in the region, future research and policy actions should take greater advantage of research spillovers through more collaboration, communication, and networking between national, regional, and international research institutions.

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

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Contents

Introduction

Germplasm movements between institutions constitute an important building block of the world agricultural research. International research institutes [e.g., the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)] have, as a policy, distributed a wide range of parental materials to breeding programs of the national agricultural research systems (NARS) and the private seed sector (ICRISAT 1995). This has contributed to faster and cost-effective development of useful final products by the receiving parties. The case of sorghum *(Sorghum bicolor* (L.) Moench) variety S 35, a pure line developed from the ICRISAT breeding program in India, and later advanced and promoted in Cameroon and Chad, is an outstanding example of this. The impact of this sort of research spillover effect is not well known and needs to be quantified. Such information could be vital to both national and international research systems in planning future agricultural research collaboration and in promoting regional networking in crops improvement research.

The main objective of this paper is to estimate the benefits and agriculture research spillover effects in the case of S 35 in Cameroon and Chad, individually and as a whole.

The remainder of the paper is structured as follows: the next section describes the germplasm movement in the research process, which led to the development of the S 35 technology. The third section presents the survey design used in tracking the spread of S 35 in the study sites. It also describes the analytical framework used in assessing returns to S 35 research and diffusion investments in the two countries. The fourth section discusses the results of the study, and summary and concluding remarks are drawn finally in the last section.

Research process of the S 35 technology

S 35 is a nonphotoperiod-sensitive, high-yielding and early-maturing pure line that originated from ICRISAT's breeding program in India, and later advanced and promoted in Cameroon and Chad. Its movement from India to Africa is described below.

From India to Nigeria

Early breeding efforts on S 35 started in 1978 at ICRISAT-Patancheru in India and resulted in the development of F_2,F_3, and F_4 generations of a three-way cross [(SPV 35 X E 35-1) CS 3541] in 1980 (Rao 1983). An F_5 progeny with origin and row number M 91019 was secured and taken by Dr N G P Rao to cooperating scientists at the Institute for Agricultural Research (IAR), Samaru, Nigeria, as an entry in the Sorghum Elite Progeny Observation Nursery (SEPON)4980 (Dr D S Murty, personal communication 1996). At Samaru, a selection was made in 1981 from M 91019 with the designation S 35[1] and tested in preliminary yield trials by the IAR breeding program in 1982 at Samaru (a moderately wet area) and Kano (a drier area), Nigeria. The Samaru test results (Table 1) show a high-yielding S 35 with a vegetative cycle too short to. fit in the traditional cropping system of moderately wet areas. The Kano test, conducted by IAR scientists led by Dr N G P Rao, apparently ran into soil/pest problems and yielded data that were not amenable for analysis, thus discouraging the promotion of the variety in Nigeria (Rao 1983).

The S 35 selection was also sent to Maroua, Cameroon, in 1982 for adaptation tests, as the material showed characteristics believed to be important for sorghum improvement in semi-arid zones of Africa (Rao 1983, Kamuanga and Fobasso 1994).

From Nigeria to Cameroon

In 1982, S 35 material was sent to Dr O P Dangi, a sorghum breeder employed by the International Institute for Tropical Agriculture (IITA) in Cameroon and working in collaboration with the joint sorghum breeding program of the

Table 1. On-station trial of sorghum variety S 35 at Samaru, Nigeria (1982 rainy season).

Selection	Pedigree	Plant height (cm)	Days to 50% flowering	Grain yield (kg ha^{-1})
S 35	M 91019	190	62	4489
S 36	M 90411	157	71	4045
S 37	M 36170	207	81	4111
Local control	Farafara	427	108	2733

Source: Rao 1983, p. 28.

1. Note that the prefix S in the designation of the variety stands for Samaru, where the material was selected in 1981 from the F_5 progeny with origin and row number M 91019.

Table 2. Grain yields (kg ha^{-1}) of sorghum varieties in on-farm tests in northern Cameroon, 1984-87.

Year	1984	1985	1986	1987	1984-87
Rainfall[1] (mm)	529	729	773	614	661
Yields of S 35	1333	1689	1866	1888	1694
Yields of local varieties	717	1531	1721	1825	1451
Yields of other improved varieties	784	1202	2185	1974	1537
Number of sites	88	79	38	35	240
Yield difference:					
S 35 over locals (%)	85	9.7	8.4	3.5	26.7

1. Mean total across selected sites.
2. Mean yields of E 35-1 and E 38-3 in 1984; S 34, S 36, S 20, and 82 S 50 in 1985; CS 54 and CS 61 in 1986 and 1987.

Source: Adapted from Kamuanga and Fobasso 1994, p. 96 (Table 1).

Institut de la recherche agronomique (IRA) and the National Cereals Research and Extension Project (NCRE) at Maroua. On-farm testing of the material in Cameroon started during the 1983 rainy season with no exciting results in comparison with farmers' local varieties (Johnson et al. 1986). In 1984, however, test results produced a resounding success, as overall comparison across 88 test sites showed a 85% mean increase in S 35 yield over farmers' local varieties (Johnson et al. 1986, Kamuanga and Fobasso 1994). Testing of the variety continued extensively in subsequent years in a total of 240 farmers' fields in addition to multilocational tests in 17 locations. The results, reported by Kamuanga and Fobasso (1994), are presented in Table 2. They clearly indicate an overwhelming superiority of S 35 in 1984 (a year of extremely low rainfall) and a slight superiority over farmers' local varieties in 'normal' rainfall years, such as in 1985,1986, and 1987.

On the basis of its high and stable performance, S 35 was released in 1986 for extension in northern Cameroon with great excitement and anticipation that the variety was on its way to widespread adoption (Kamuanga and Fobasso 1994). The release was supported by a campaign for a large-scale seed multiplication. According to Kamuanga and Fobasso (1994), 20 t of S 35 seed was produced at the time of its release by the government's Seed Multiplication Project at Maroua. This was in response to increased demand for seed of the variety. Kamuanga and Fobasso also reported that for the 1986/87 cropping season alone, the Societe de du developpement du coton (SODECOTON) extended the S 35 technology on more than 600 ha in northern Cameroon. In 1986, the variety crossed the borders into neighboring Chad.

From Cameroon to Chad

During the 1979-1982 Chadian civil war all research structures and infrastructures were virtually destroyed together with the country's genetic material banks. Thus after the war, frequent prospecting was organized into neighboring countries with similar agroecological zones with the goal to replenish genetic material banks. It was in this context that the S 35 variety was introduced in Chad in 1986 from IRA's breeding program at Maroua, Cameroon. It was immediately tested on-station at Gassi and found to be high yielding and resistant to long smut (*Tolyposporium ehrenbergii* (Kuhn) Patouillard) (Table 3), a yield-reducing sorghum disease prominent in Chad (Saleh et al. 1994). On the basis of this encouraging preliminary result, the material was quickly advanced to on-farm testing in the following year (1987). In anticipation of subsequent extension activities a large-scale seed multiplication was started by the Food and Agriculture Organization of the United Nations/ United Nations Development Programme (FAO/UNDP)-supported seed project at Gassi. The on-farm tests were multiloational and conducted by agents of the Office national de developpement rural (ONDR) as well as many nongovernmental organizations (NGOs) operating in potential release and diffusion zones targeted by S 35 research. Unfortunately, these tests have not been sufficiently documented to allow a clear appreciation of the performance of the technology that led to its release in 1989. Tables 4 and 5 summarize the scant information on the on-farm nd regional testing of S 35 in Chad.

The regional yield trials (Table 4) produced mixed results as the S 35 technology performed well at Guera, outyielding the local variety by 74%; while in the adjacent region of Chari-Baguirmi, the technology yielded only 830 kg ha^{-1} against 1036 kg ha^{-1} for the local control. These mixed results led the ONDR to intensify the promotion of the technology in the Guera region

Table 3. Characteristics of sorghum variety S 35 in on-station testing at the Gassi research station, Chad, 1986.

Varieties	Days to maturity	Tolerance to drought	Resistance to long smut	Plant height (cm)	Grain color	Grain yield (kg ha^{-1})
S 35	106	Tolerant	Resistant	235	Ivory white	2602
E 38-3	106	Tolerant	Resistant	230	Ivory white	1816
Nadj-dadj (local control)	126	Sensitive	Resistant	310	Red	1400

Source: Centre seraencier de Gassi 1989.

Table 4. Grain yield (kg ha^{-1}) of sorghum variety S 35 in regional trials in Chad, 1988.

Varieties	Regions		
	Guera	Chari-Baguirmi	All sites
S 35	1416	830	1123
E 38-3	1411	1408	1409
Nadj-dadja rouge (local control)	810	1036	923

Source: ONDR 1988.

and away from Chari-Baguirmi. While Table 4 also shows E 38-3 to be a more stable, high yielding introduced variety, it has never been released because of its high susceptibility to long smut.

The S 35 extension activities summarized in Table 5 present the major management practices associated with the adoption of S 35 in Chad: (1) late sowing: 2 to 3 weeks after farmers' local varieties have been sown (usually late May to early June); (2) sowing density: use of full quantity of mini-doses of 250 g seed to be sown to 0.25 ha (i.e., 10 kg ha^{-1}); (3) line sowing after plowing; and (4) field cleanliness: at least two weedings before harvest.

Table 5. On-farm trials of S 35 conducted by Action internationale contre la faim (AICF) in Arenga (Guera), Chad, 1989.

	Villages					
Items	Arenga	Mankoussine	Male	Doyo II	Niegui	All sites
No of farmers	5	2	3	2	6	18
Quantity of mini-doses	5	2	3	2	6	18
Sowing dates	27-28/06	26/6-3/7	26/6-3/7	29/6-4/7	10-29/6	10/6-4/7
Use full doses	Yes (100%)	Yes (100%)	Yes (100%)	Yes (100%)	Yes (100%)	Yes (100%)
Plowing/line sowing	Yes (40%)	Yes (50%)	No (100%)	Yes (100%)	No (100%)	Yes (78%)
Field cleanliness	80%	100%	50%	50%	38%	63%
Harvesting dates	2-12/11	11-14/11	26/10-4/11	25/10-3/11	26/9-15/11	26/9-15/11
Mean yield (kg ha^{-1})	1771	1588	983	1050	1060	1204

Source: AICF 1990.

Table 6. Steps in the research process leading to the release of S 35 in Cameroon and Chad

1978/79	Selection was made from a landrace at ICRISAT-Patancheru and F_2, F_3, and F_4 generations of a three-way cross [(SPV 35 X E 35-1) CS 3541] were, developed.
1980	An F_5 progeny with row number M 91019 was secured and taken to cooperating scientists at the Institute for Agricultural Research (IAR) at Samaru, Nigeria, through the Sorghum Elite Progeny Observation Nursery (SEPON), 1980.
1981	A selection was made at Samaru by N G P Rao from M 91019 with the designation S 35.
1982	S 35 was unsuccessfully tested in preliminary yield trials in Samaru and Kano by the IAR breeding program. This discouraged further promotion of the variety in Nigeria. S 35 was sent to northern Cameroon for further evaluation in the joint sorghum breeding program of the Institut de la recherche agronomique (IRA) and the National Cereals Research and Extension Project (NCRE).
1983	On-farm testing of the material in Cameroon started with no exciting results.
1984	S 35 test results produced a resounding success as overall comparison across 88 test sites showed a 85% mean increase in S 35 yield over farmers' local varieties.
1986	S 35 was released for extension in northern Cameroon; the variety crossed the border to Chad in the same year.
1986-88	On-station and on-farm testing of S 35 continued in Chad, with parallel large-scale seed multiplication supported by the Food and Agriculture Organization of the United Nations/United Nations Development Programme (FAO/UNDP) seed project at Gassi.
1989	S 35 was released in Chad.

Line sowing after plowing and field cleanliness are the major determinants of S 35 grain yield, as most farmers who have on average practiced these two activities on more than 50% of their field have achieved an average grain yield of more than 1000 kg ha^{-1}. In 1989, the S 35 technology was released for extension in Chad with the Prefecture of Guera as the targeted zone and Chari-Baguirmi and Mayo-Kebbi as possible diffusion areas. The distinguishing features of these three regions (which are also the study sites) are described by Yapi et al. (1997). Table 6 summarizes the research and testing process that led to the release of S 35 in the study zones.

Methodology

The survey method used to track and quantify the spread of the S 35 technology is described in this section together with the analytical framework used to guide the impact evaluation process.

Survey design

A structural survey questionnaire with multiple modules was used in each country to collect farm-level information necessary for the impact evaluation. The modules were designed to collect farm-level information on cropping systems, adoption patterns, farmers' perceptions, farm production and cost structure, and seed, labor, farm equipment, and fertilizer inputs utilization. The surveys were conducted in 1995 and covered the periods 1986-1995 (for Cameroon) and 1990-95 (for Chad).

A multiple stage sampling scheme was carefully designed to ensure that selected samples of participating farmers in each country were representative of the study sites. The first stage of sampling consisted of reviewing national agricultural statistics and purposively selecting regions targeted by the release and diffusion of S 35 in each country. Thus, the prefectures of Mayo-Kebbi, Chari-Baguirmi, and Guera in Chad, and the zones of Mayo-sava, Diamare, and Mayo-Danay in northern Cameroon were selected for study. Tables 7, 8, and 9 show background information on rainfed 'sorghum area, production, and price in the selected regions. The second stage consisted of a random selection of subprefectures in Chad and subzones ('arrondissements') in Cameroon.

The third and fourth stages consisted of a random and proportional selection of representative villages and farmers[2]. A total of 571 participating farmers were selected in Cameroon from 33 villages in 17 arrondissements within the three purposively chosen zones. Similarly in Chad, 152 participating farmers were selected from 28 villages in four subprefectures within the three purposively chosen prefectures (further sampling information is available in Yapi et al. 1997, and Njomaha et al. 1997). Figure 1 presents a map of Chad showing the regions of study and the adjacent study zones in northern Cameroon .

2. The arrondissements and subprefectures were not all equal, thus greater numbers of villages were randomly selected from larger arrondlssements/subprefectures than from the smaller ones. The number of randomly selected farmers was also proportional to the size of village populations.

Table 7. Background information on sorghum area (ha), production output (t), and price (CFA francs kg^{-1}) in the study regions of Chad, 1986–1994.

Year	Guéra			Mayo-Kebbi			Chari-Baguirmi			All three regions		
	Area	Output	Price	Area	Output	Price	Area	Output	Price	Area	Output	Mean price
1986	46 727	31 238	43.52	45 120	31 818	47.30	19 339	11 295	45.41	111 186	77 251	44.39
1987	46 298	30 788	27.97	51 471	37 494	30.40	28 818	15 395	29.18	126 587	89 521	29.18
1988	35 910	25 137	65.04	54 940	54 720	70.70	40 661	30 089	67.87	131 511	109 946	60.87
1989	56 983	39 880	57.13	62 394	43 301	62.10	35 070	16 057	59.62	154 447	99 274	59.62
1990	46 100	23 050	52.26	73 900	50 400	56.80	50 500	26 260	54.53	170 500	99 710	54.53
1991	48 000	32 200	74.34	81 000	57 750	80.80	79 000	61 540	77.57	208 000	151 490	77.57
1992	43 400	33 000	44.60	83 500	63 043	68.40	107 700	96 800	52.40	234 600	192 843	52.40
1993	32 700	16 330	34.80	89 300	59 473	42.80	62 300	31 075	38.50	184 300	106 878	38.50
1994	49 000	33 320	110.30	93 074	92 701	96.80	91 913	71 874	109.30	233 987	197 895	109.30

Source: Ministère du plan et de la coopération 1995, various pages.

Table 8. Background information on sorghum area (ha), production output (t), and price (CFA francs kg^{-1}) in the study regions of Cameroon, 1983–1994.

Year	Mayo-Sava			Diamaré			Mayo-Danay			All three regions		
	Area	Output	Price	Area	Output	Price	Area	Output	Price	Area	Output	Mean price
1983	51 347	35 573	71.9	21 036	10 994	60.5	19 042	15 043	57.5	91 425	61 610	63.3
1984	77 700	53 342	234.6	32 081	18 435	197.3	29 646	20 606	187.7	139 427	92 383	206.5
1985	73 621	81 134	77.5	30 397	27 917	65.2	28 090	30 853	62.0	132 107	139 904	68.2
1986	92 434	129 750	90.8	21 309	24 058	66.0	34 384	36 725	82.8	148 768	190 533	79.8
1987	82 900	90 732	86.8	29 221	33 750	78.8	28 648	36 641	72.0	140 768	157 123	79.2
1988	81 070	116 477	97.1	32 430	34 670	72.5	27 931	29 749	57.0	141 431	180 896	75.5
1989	75 661	90 600	88.1	33 740	36 092	73.6	32 169	32 505	66.4	141 570	159 197	76.0
1990	75 612	52 115	100.0	30 940	28 314	80.8	27 133	24 618	76.7	133 685	105 047	85.8
1991	75 424	91 108	96.8	32 523	23 646	80.9	34 868	48 990	80.7	142 815	163 744	86.1
1992	82 414	87 901	96.5	36 356	35 601	90.0	36 106	40 132	84.2	155 176	163 634	90.2
1993	75 441	60 495	95.9	35 656	25 754	96.1	26 663	24 832	88.0	137 760	111 081	93.3
1994	73 492	80 049	112.2	41 656	41 362	91.0	20 019	18 697	86.9	134 967	140 108	96.7

Source: Njomaha et al. 1997, p. 7.

Table 9. Background information on aggregate sorghum area, production, and price across study sites and countries, 1986-1994.

Year	Cameroon and Chad as a whole		
	Area (ha)	Production (t)	Mean price (CFA francs t^{-1})
1986	159 313	264 884	62 605
1987	267 355	240 800	54 190
1988	272 942	290 842	71 685
1989	296 017	258 435	67 810
1990	304 185	204 757	70 165
1991	350 815	315 234	81 835
1992	389 776	356 477	71 300
1993	322 060	217 959	65 900
1994	368 954	338 003	103 00

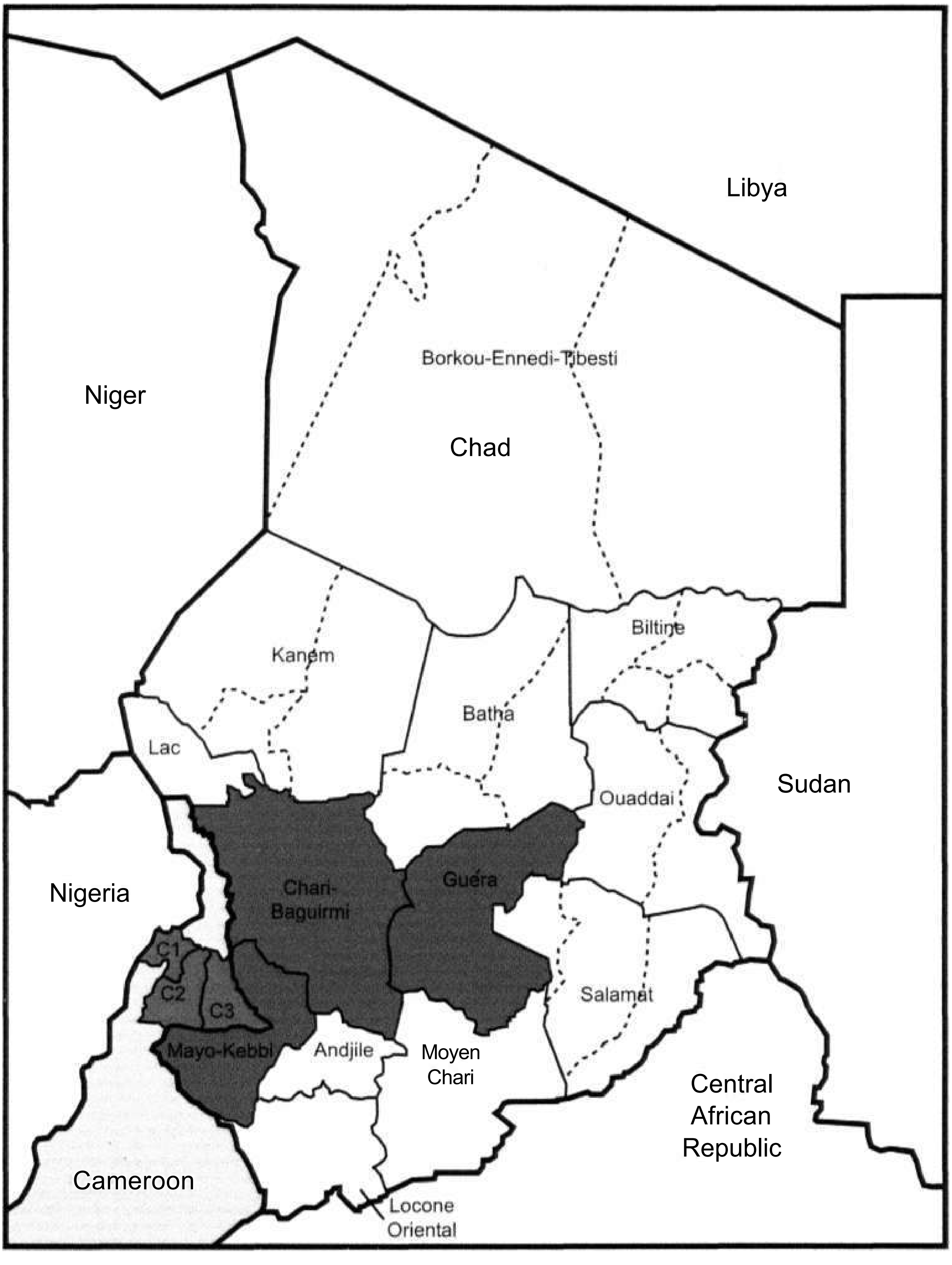
Analytical method

The welfare gains from S 35 research and diffusion in Chad and Cameroon were estimated using the economic surplus framework. Because international trade in sorghum is practically nonexistant in Chad, a simple nontraded goods version of the economic surplus model is considered. This simple framework is a single period static model of a closed economy with parallel shift in the supply function. It compares economic surpluses with and without S 35 research and diffusion. To arrive at net present values (NPV) of the streams of benefits from S 35 research and diffusion it was necessary to account for S 35 research and diffusion costs in each country.

Research and diffusion costs estimation

As indicated earlier (Table 6), S 35 research and development (R&D) started at ICRISAT-Patancheru and continued in Nigeria, Cameroon, and Chad. But for the purpose of this study, which seeks to quantify the impact of the spillover effect of the technology, only expenditures incurred by research and extension institutions in Chad and Cameroon are considered. All S 35 related R&D expenditures incurred in India and Nigeria are treated as 'sunk costs,' that is, costs that would have occurred anyway without spillover. Thus, S 35 research and diffusion costs estimation looked only at S 35 related research and diffusion activities and budgets at concerned institutions in the two countries.

Figure 1. Map showing the study regions in Chad[1] and Cameroon[2].



1. The study regions in Chad- Chari-Baguirmi.Guera, and Mayo-Kebbi- are in blue color.
2. The study regions in northern Cameroon are indicated in red, and are numbered C1 (for the region of Mayo Sava), C2 (for the region of Diamare), and C3 (for the region of Mayo-Danay).

Table 10. Estimated research and diffusion costs (US$) for S 35 sorghum variety incurred by research and extension institutions in Cameroon.

Year	S 35 research and extension institutions in Cameroon				Total costs
	IRA[1]	TLU/SAFGRAD[2]	SODECOTON[3]	Others[4]	
1982	31 405	0	0	0	31 405
1983	34 545	10 030	482	0	45 057
1984	0	25 027	3 980	0	29 006
1985	203	34 306	5 242	17 072	56 823
1986	203	20 106	6 000	18 658	44 966
1987	203	10 967	2 000	13 543	26 713
1988	203	18 700	1 541	11 104	31 547
1989	203	0	1 228	10 583	12 014
1990	0	0	3 100	13 703	16 803
1991	0	0	3 133	5 222	8 355
1992	0	0	0	5 000	5 000
1993	0	0	0	5 000	5 000
1994	3 036	0	0	7 000	10 036
1995	3 036	0	0	7 000	10 036

1. Institut de la recherche agronomique.
2. Testing and Liaison Unit/Semi-Arid Food Grain Research and Development.
3. Societe de developpement du coton.
4. Others include: projet semencier, a public seed multiplication project; Delegations d'agriculture, public-rural agriculture development units involved in S 35 seed distribution; the Centre de formation des jeunes agricultueurs (CFJA); and NGOs and missionaries.

Source: Njomaha et al. 1997, p. 20; and Johnson et al. 1986.

Table 11. Estimated research and diffusion costs (US$) for the S 35 sorghum variety incurred by research and extension institutions in Chad.

Year	S 35 research and extension institutions in Chad			Total costs
	Gassi research station	ONDR[1]	AICF[2]	
1986	46 112	0	0	46 112
1987	46 112	0	0	46 112
1988	46 112	0	0	46 112
1989	46 112	52 572	26 644	125 328
1990	46 112	52 572	31 489	130 173
1991	46 112	52 572	26 644	125 328
1992	46 112	52 572	19 378	118 062
1993	46 112	52 572	0	98 684
1994	23 056	52 572	0	75 628
1995	23 056	52 572	0	75 628
1996	23 056	25 235	0	48 291

1. Office national de development rural.
2. Action Internationale centre le faim.

Source: Yapi et al. 1997, pp. 20-23.

For Chad, these institutions included the Gassi research station, ONDR, and the Action internationale contra la faim (AICF), a French NGO operating for hunger relief in the Sahelian zone of Chad. For Cameroon, costs incurred by IRA-Maroua, SODECOTON, the Testing and Liaison Unit of the Semi-Arid Food Grain Research for Agricultural Development (TLU/SAFGRAD)], and the National Extension and Seed Services are considered. The estimated costs for S 35 research and diffusion in Cameroon are presented in Table 10 and for Chad in Table 11. Yapi et-al. (1997) and Njomaha et al. (1997) describe the methodology of estimating these costs.

Results and discussion

The results of the on-farm inquiries and the welfare gain estimations are presented and discussed in this section.

Results of the adoption study

Patterns of adoption

Results of the adoption survey clearly indicated that farmers in drought-prone regions of Chad and Cameroon have started substituting the short duration S 35 for their long-cycle landraces (Djigari, Nadj-dadja, Kouran, and Wakas varieties). Adoption rates were estimated in two ways: (1) as the percentage area of total rainfed sorghum sown to the S 35 variety; and (2) as the percentage of farmers adopting the technology. The estimated adoption rates are presented in Table 12.

Ten years after its release in northern Cameroon, the technology has spread over about 50% of the total rainfed sorghum area in Mayo-Sava where 85% of the farmers have adopted it. The spread of the variety has been less spectacular in the other two study zones in Cameroon, where about 20% of farmers cultivate S 35 on less that 15% of their rainfed sorghum fields. These zonal differences in adoption rates are explained mainly[3] by differences in annual rainfall, which average 687 mm in Mayo-Sava against 819 mm in Diamare and 811 mm in Mayo-Danay. The lower the annual rainfall, the more valuable short duration varieties become.

3. Other possible explanations include: (a) the proximity of Mayo-Sava region to Nigeria, allowing easy access to commercial fertilizers at competitive prices given a favorable exchange rate between the CFA franc and Naira; and (b) the fact that S 35 has become quite marketable in Mayo-Sava compared to Diamare and Mayo-Danay. Although data are not available tp support these observations, farmers in the Mayo-Sava zone have cited the marketability of S 35 as a reason for their adopting the variety.

Table 12. Farm-level survey data on S 35 sorghum variety adoption rates (as % of total rainfed sorghum area) in Chad and Cameroon.[1]

Year	S 35 adoption rates by study zones in Cameroon				S 35 adoption rates by study regions in Chad				Aggregation over the two countries
	Mayo-Sava	Diamaré	Mayo-Danay	All three zones	Guéra	Mayo-Kebbi	Chari-Baguirmi	All three regions	
1986	10.60 (8)	6.50 (6)	0.40 (1)	8.13	—	—	—	—	5.85
1987	15.40 (9)	7.50 (7)	0.40 (1)	11.04	—	—	—	—	7.18
1988	20.30 (10)	6.00 (5)	5.80 (4)	15.06	—	—	—	—	9.34
1989	30.10 (19)	4.20 (4)	1.60 (2)	18.44	—	—	—	—	11.43
1990	36.00 (31)	3.60 (3)	14.50 (7)	22.38	17 (14)	7 (14)	0 (0)	7	14.84
1991	35.90 (41)	4.50 (5)	9.30 (9)	23.52	22 (23)	8 (15)	0 (0)	8	16.07
1992	39.10 (57)	5.30 (8)	9.60 (10)	24.58	23 (41)	10 (28)	14 (40)	14	21.03
1993	47.10 (78)	6.60 (15)	15.90 (15)	30.45	28 (58)	17 (47)	21 (80)	20	25.33
1994	46.50 (84)	9.80 (18)	17.70 (18)	31.65	32 (84)	22 (72)	22 (60)	24	27.21
1995	49.40 (85)	13.6 (20)	12.10 (22)	32.74	38 (84)	27 (75)	24 (80)	27	29.41

1. Numbers in parentheses are percentages of adopting farmers. The surveys were conducted at the end of the 1995 cropping season. The questionnaire was structured to obtain production information in earlier years (1994–1986) as well.

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

Farmers' perceptions

The on-farm surveys also provided useful information on farmers' perceptions of the S 35 technology. First, farmers have indicated a preference for S 35 over their traditional varieties because the new variety was early-maturing and high-yielding with good food and fodder quality. This was true across ail study sites. The short-duration trait of S 35 was an obvious advantage in drought-prone areas where farmer's long-cycle traditional landraces often failed when rains came late and/or ended too soon. In addition, farmers in Mayo-Sava (Cameroon) and Guera (Chad) have cited the immerging high market value of white-grain sorghum as an important reason for using the S 35 variety. Indeed in the Mayo-Sava zone, a typical bag of 100 kg of white-grain sorghum was valued at CFA francs 9000 (250 CFA_1 francs = US$ 1.00) against CFA francs 7000 for the most popular red-grain local Djigari varieties (Njomaha et al. 1997). Similarly, in the Guera zone of Chad, observed local markets prices for white-grain sorghums were higher than prices of local red-grain varieties. This price differential is certainly related to the good food quality of the S 35 flour.

Second, farmers were willing to change their management practices for S 35 and not for their local sorghum varieties because the required changes[4] are simple, familiar, and easy to implement locally from available family and animal labor. Furthermore, payoffs for making these changes are substantial, including food security, production efficiency,and unit production cost reduction.

4. See Yapi et al. 1997 for a more detailed presentation of the required management practices in S 35 farming, and the associated payoffs (yield gain).

Constraints to adoption

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

Bird attack is a consequence of both the early maturity of the S 35 variety and the sweetness of its grain. Use of appropriate sowing dates combined with wide adoption of the S 35 variety should significantly mitigate this constraint. The grain mold problem is related to the fact that the variety matures at a time when rain continues. Harvesting S 35 immediately after maturity should prevent this problem. As for the constraints of soil infertility, lack of seed, and the high cost of grinding, they are structural in nature. Their resolution will require a strong political will and major policy changes regarding farm credit, purchase input prices, and incentives for private sector involvement in the establishment of an efficient, self-sustained seed sector.

Assessment of benefits from S 35 adoption

In this section, quantitative indicators of the benefits from the adoption of S 35 are assessed. The assessment is based on a set of premises regarding:

- base price and production levels,
- farm cost structure,
- adoption ceiling, and
- demand and supply elasticity estimates.

The base price and output levels used in the impact evaluation were 1983-85 averages (for Cameroon) and 1986-88 averages (for Chad) computed from secondary data (Tables 7 and 8). This country-level base information was averaged to obtain base price and output levels for the aggregate (across-country) analysis (Table 9).

The analyses of farm cost structure of S 35, compared with farmers' best local varieties, were based on farm-level survey data on inputs, outputs, and production costs. These analyses indicate that the use of S 35, as opposed to farmers' best local varieties, reduces unit cost of production by as much as 20%, or CFA francs 11 661 per ton for Chad and Cameroon as a whole. The unit cost reduction is even more significant for Chad where it reaches 33%, or CFA

Table 13. Summary of the farm of cost structure analyses by study sites and across sites for S 35 and a local sorghum variety.

Study site	Total variable costs (CFA francs)		Yield (t ha^{-1})			Unit variable costs (CFA francs t^{-1})		Unit variable cost reduction (CFA francs t^{-1})
	Local variety	S 35 variety	Local variety	S 35 variety	S 35 yield advantage (%)	Local variety	S 35 variety	
Cameroon	85 899	86 187	1.36	1.55	14	63 161	55 607	7 557
Mayo-Sava	94 293	95 048	1.22	1.65	36	77 500	57 700	19 800
Diamaré	92 435	90 918	1.45	1.54	6	63 500	58 900	4 600
Mayo-Danay	70 968	72 593	1.42	1.47	4	50 000	49 300	700
Chad	61 412	69 940	0.76	1.15	51	80 805	60 817	19 987
Guéra	63 400	71 750	0.71	1.09	54	89 296	65 825	23 471
Mayo-Kebbi	35 875	45 105	0.78	1.19	53	45 994	37 903	8 091
Chari-Baguirmi	54 890	58 940	0.81	1.18	46	67 765	49 949	17 816
All sites	73 655	78 064	1.06	1.35	27	69 486	57 825	11 661

francs 19 987. Table 13 summarizes these cost analyses. Total cost of production is larger for S 35 than for the farmers' best local variety. Elements of additional cost were mainly from land preparation, hauling of output, bird scaring, and chemical fertilizers. This last element - the use of chemical fertilizers - concerned mostly Cameroon, particularly the Mayo-Sava zone where farmers were able to purchase fertilizers from neighboring Nigeria at below domestic prices. Because S 35 yielded more output per hectare, its unit cost of production was lower than that of farmers' best local varieties. Indeed, across all study sites in the two countries, S 35 yielded 27%, or 290 kg ha^{-1}, more output than the farmers' best traditional variety (Table 13). Land preparation for S 35 farming entailed additional costs because it required plowing and row ridging using animal traction. Because S 35 was high yielding, the hauling of its output also required more time and thus more costs. Finally, the susceptibility of the technology to bird attack has made bird scaring a necessary crop protection activity. This labor-intensive activity, usually undertaken by children, adds to S 35 production costs.

In order to evaluate the streams of benefits from the use of the S 35 technology, adoption rates estimated for the survey years (1986-1995 for Cameroon and 1990-95 for Chad) were subsequently projected forward and backward over the nonsurvey years, following the logistic function. Ceiling rates of 50% (for the whole of the study zones in Chad) and 35% (for the study zones in Cameroon) were set in the projection process. The rationale for setting these ceilings is based on current adoption constraints described by farmers and the poor likelihood for these constraints to be resolved to any significant degree in the medium term.

Elasticity estimates of -0.30, for demand and 0.50 for supply were set for Chad. For Cameroon, elasticity estimates were set at -0.5 for demand and 0.7 for supply. The basis of these elasticity levels is the fundamental observation that sorghum remains a subsistence crop, whose production meets serious constraints in the study regions of both Cameroon and Chad. Thus, sorghum supply and demand are less likely to respond significantly to price changes in the short/medium term. Table 14 presents summary data for benefits assessment of S 35 for Cameroon and Chad, individually and as a whole.

5. Note that estimated NPV of benefits over the two countries is less than the sum of the benefits to individual countries. This is because the large benefits to Chad, resulting from the very short S 35 R&D process in that country (1986-89) has now been eroded through the data polling process in which Chad data are subject to relatively longer S 35 R&D in Cameroon (1981-85). This is an argument for research spillovers, which can tremendously reduce costs of R&D and accelerate the release and adoption of agricultural technologies in the region.

Table 14. Summary of data for benefits assessment of S 35 sorghum variety for Cameroon and Chad individually and as a whole.

Summary items	Cameroon	Chad	Cameroon and Chad as a whole
Base level of annual production	97 966 t[1]	93 997t[2]	95 982t[4]
Base price level (CFA francs t^{-1})	112 692[1]	44 810[3]	78 751[4]
Supply elasticity	0.70	0.50	0.60
Demand elasticity	-0.50	-0.30	-0.40
Discount rate used for the assessment	0.10	0.10	0.10
Unit variable cost reduction (CFA francs t^{-1})	7557	19 987	11 661
Slope of supply curve	0.60853	1.048848	0.731282
Slope of demand curve	0.43466	0.629309	0.487521
Exchange rate (US$ 1)	CFA francs 250	CFA francs 250	CFA francs 250

1. 1983–85 averages of production and price.
2. 1986–89 average.
3. 1986–88 average.
4. Average of base price levels for Cameroon and Chad.

Table 15. Evaluation of benefits from S 35 sorghum research and diffusion: aggregate analysis for the three study regions in Chad.[1]

Year	Net benefits (US$)	Estimated research costs: Total (US$)	Gassi[2,3] (CFA francs)	ONDR[4] (CFA francs)	AICF[5] (CFA francs)	Estimated research gains: Total	Adoption level	Annual gains	Distribution of benefits (US$): Gains to consumers	(%)	Gains to producers	(%)
Net present value (NPV)	15 093 740	685 088	85 909 021	92 743 537	20 874 745	23 101 782		73 359 649	14 438 614		8 663 168	
Total value	91 721 671	1 997 853	236 324 820	237 099 720	26 038 650	93 719 523		227 056 489	89 402 351		35 144 821	
1986	-46 112	46 112	11 528 040	0	0	0	0	0	0	0	0	0
1987	-46 112	46 112	11 528 040	0	0	0	0	0	0	0	0	0
1988	-46 112	46 112	11 528 040	0	0	0	0	0	0	0	0	0
1989	-125 328	125 328	11 528 040	13 143 000	6 661 050	0	0	0	0	0	0	0
1990	417 895	130 173	11 528 040	13 143 000	7 872 150	548 067	0.07	7 829 534	342 542	62.5	205 525	37.5
1991	501 034	125 328	11 528 040	13 143 000	6 661 050	626 363	0.08	7 829 534	391 477	62.5	234 886	37.5
1992	978 073	118 062	11 528 040	13 143 000	4 844 400	1 096 135	0.14	7 829 534	685 084	62.5	411 051	37.5
1993	1 467 223	98 684	11 528 040	13 143 000	0	1 565 907	0.20	7 829 534	978 692	62.5	587 215	37.5
1994	1 803 460	75 628	5 774 020	13 143 000	0	1 879 088	0.24	7 829 534	1 174 430	62.5	704 658	37.5
1995	2 038 346	75 628	5 774 020	13 143 000	0	2 113 974	0.27	7 829 534	1 321 234	62.5	792 740	37.5
1996	2 613 751	48 291	5 764 020	6 308 640	0	2 662 042	0.34	7 829 534	1 663 776	62.5	998 266	37.5
1997	2 926 932	48 291	5 764 020	6 308 640	0	2 975 223	0.38	7 829 534	1 859 514	62.5	115 709	37.5
1998	3 240 114	48 291	5 764 020	6 308 640	0	3 288 404	0.42	7 829 534	2 055 253	62.5	1 233 152	37.5
1999	3 396 704	48 291	5 764 020	6 308 640	0	3 444 995	0.44		2 153 122	62.5	1 291 873	37.5
2000	3 553 295	48 291	5 764 020	6 308 640	0	3 601 586	0.46	7 829 534	2 250 514	62.5	1 350 595	37.5
2001	3 631 590	48 291	5 764 020	6 308 640	0	3 679 881	0.47	7 829 534	2 299 926	62.5	1 379 955	37.5
2002	3 709 886	48 291	5 764 020	6 308 640	0	3 758 176	0.48	7 829 534	2 348 860	62.5	1 409 316	37.5
2003	3 788 181	48 291	5 764 020	6 308 640	0	3 836 472	0.49	7 829 534	2 397 795	62.5	1 438 677	37.5
2004	3 788 181	48 291	5 764 020	6 308 640	0	3 836 472	0.49	7 829 534	2 397 795	62.5	1 438 677	37.5
2005	3 866 476	48 291	5 764 020	6 308 640	0	3 914 767	0.50	7 829 534	2 446 729	62.5	1 468 038	37.5
2006	3 866 476	48 291	5 764 020	6 308 640	0	3 914 767	0.50	7 829 534	2 446 729	62.5	1 468 038	37.5
2007	3 866 476	48 291	5 764 020	6 308 640	0	3 914 767	0.50	7 829 534	2 446 729	62.5	1 468 038	37.5
2008	3 866 476	48 291	5 764 020	6 308 640	0	3 914 767	0.50	7 829 534	2 446 729	62.5	1 468 038	37.5
2009	3 866 476	48 291	5 764 020	6 308 640	0	3 914 767	0.50	7 829 534	2 446 729	62.5	1 468 038	37.5
2010	3 866 476	48 291	5 764 020	6 308 640	0	3 914 767	0.50	7 829 534	2 446 729	62.5	1 458 038	37.5
2018	3 866 476	48 291	5 764 020	6 308 640	0	3 914 767	0.50	7 829 534	2 446 729	62.5	1 468 038	37.5

1. IRR = 0.9517.
2. Gassi research station
3. CFA francs 250 = US$ 1.
4. Office national de développement rural.
5. Action internationale contre la faim.

Table 16. Evaluation of benefits from S 35 sorghum research diffusion: aggregate analysis for the three study zones in Cameroon.[1]

Year		Estimated research costs (US$)					Estimated research gains (US$)			Distribution of benefits (US$)			
	Net benefits (US$)	Total	IRA-Maroua[2]	TLU/SAF-GRAD[3]	SODE-COTON[4]	Extension seed service	Total gains	Adoption level	Annual gains	Gains to consumers	(%)	Gains to producers	(%)
Net present value (NPV)	4 626 105	255 452	66 457	86 673	17 280	97 085	7 147 088		28 614 121	1 063 455		759 611	
Total value	29 858 396	599 360	142 863	119 134	26 706	274 885	30 457 756		98 675 236	4 531 981		3 237 129	
1982	-31 405	31 405	31 405	0	0	0							
1983	-45 057	45 057	34 545	10 030	482	0							
1984	-46 079	46 079	0	25 027	3 980	0							
1985	-56 823	56 823	203	34 306	5 242	17 072							
1986	198 134	44 966	203	20 106	6 000	18 658	243 100	0.0813	2 990 159	36 172	58.3	25 837	41.7
1987	303 401	26 713	203	10 967	2 000	13 543	330 114	0.1104	2 990 159	49 119	58.3	35 085	41.7
1988	418 771	31 547	203	18 670	1 541	11 104	450 318	0.1506	2 990 159	67 005	58.3	47 861	41.7
1989	520 672	30 713	203	0	1 228	10 583	551 385	0.1844	2 990 159	82 044	58.3	58 603	41.7
1990	652 394	16 803	0	0	3 100	13 703	669 198	0.2238	2 990 159	99 574	58.3	71 124	41.7
1991	694 931	8 355	0	0	3 133	5 222	703 285	0.2352	2 990 159	104 646	58.3	74 747	41.7
1992	729 981	5 000	0	0	0	5 000	734 981	0.2458	2 990 159	109 362	58.3	78 116	41.7
1993	905 503	5 000	0	0	0	5 000	910 503	0.3045	2 990 159	135 479	58.3	96 771	41.7
1994	936 349	10 036	3 036	0	0	7 000	946 385	0.3165	2 990 159	140 818	58.3	100 584	41.7
1995	968 942	10 036	3 036	0	0	7 000	978 978	0.3274	2 990 159	145 668	58.3	104 048	41.7
1996	991 667	10 036	3 036	0	0	7 000	1 001 703	0.3350	2 990 159	149 049	58.3	106 464	41.7
1997	1 006 917	10 036	3 036	0	0	7 000	1 016 953	0.3401	2 990 159	151 318	58.3	108 084	41.7
1998	1 017 084	10 036	3 036	0	0	7 000	1 027 120	0.3435	2 990 159	152 831	58.3	109 165	41.7
1999	1 023 662	10 036	3 036	0	0	7 000	1 033 698	0.3457	2 990 159	153 810	58.3	109 864	41.7
2000	1 028 147	10 036	3 036	0	0	7 000	1 038 183	0.3472	2 990 159	154 477	58.3	110 341	41.7
2001	1 030 838	10 036	3 036	0	0	7 000	1 040 874	0.3481	2 990 159	154 878	58.3	110 627	41.7
2002	1 032 931	10 036	3 036	0	0	7 000	1 042 967	0.3488	2 990 159	155 189	58.3	110 849	41.7
2003	1 034 127	10 036	3 036	0	0	7 000	1 044 163	0.3492	2 990 159	155 367	58.3	110 976	41.7
2004	1 035 024	10 036	3 036	0	0	7 000	1 045 060	0.3495	2 990 159	155 500	58.3	111 072	41.7
2005	1 035 323	10 036	3 036	0	0	7 000	1 045 359	0.3496	2 990 159	155 545	58.3	111 104	41.7
2006	1 035 662	10 036	3 036	0	0	7 000	1 045 658	0.3497	2 990 159	155 589	58.3	111 135	41.7
2007	1 035 922	10 036	3 036	0	0	7 000	1 045 958	0.3498	2 990 159	155 634	58.3	111 167	41.7
2008	1 036 221	10 036	3 036	0	0	7 000	1 046 257	0.3499	2 990 159	155 678	58.3	111 199	41.7
2009	1 036 520	10 036	3 036	0	0	7 000	1 046 556	0.3500	2 990 159	155 723	58.3	111 231	41.7
2018	1 036 520	10 036	3 036	0	0	7 000	1 046 556	0.3500	2 990 159	155 723	58.3	111 231	41.7

1. IRR = 0.7543.
2. Institut de la recherche agronomique.
3. Testing and Liaison Unit/Semi-Arid Food Grains Research and Development.
4. Société de développement du coton.

Given the research and diffusion costs estimates presented in Tables 10 and 11, a discount rate of 10%, and the summary data on base prices and outputs, demand and supply elasticity estimates, unit cost reduction, and exchange rate (Table 14), the NPV of benefits accruing to Chad were estimated at US$ 15 million, and US$.4.6 million for Cameroon (Tables 15 and 16), These represent internal rates of returns (IRR) of 95% (Chad) and 75% (Cameroon). When data from the two countries were pooled, estimated NPV of benefits accruing to the African region as a whole was estimated at US$ 6.6 million[5], representing an IRR of 71%. Subsequent sensibility analyses showed that these results are not sensitive to small variations in parameter values for demand and supply elasticity estimates and discount rates, except for NPV, which vary greatly with variations in the discount rate.

What if each country had to develop S 35 on its own?

The spillover effect has reduced the S 35 research and development lags (i.e., the time span from selection to release) to only five years in Cameroon (1981-85) and four years in Chad (1986-89). If each country had to develop the S 35 technological package on its own, the R&D lags would have been longer for at least two reasons[6]. First, the S 35 research in both Cameroon and Chad was reduced to adaptive research only because the materials sent to both countries were highly advanced; and second, both countries did not have the critical mass of researchers required for an efficient development of the technology. Thus, if the S 35 technological package were to be developed independently in each country, the longer research lags would have increased the R&D costs, which in turn would have reduced the net benefits associated with the utilization of the technology.

To illustrate this, let's assume that NARS scientists in Cameroon and Chad were as efficient as their ICRISAT counterparts, so that S 35 R&D lags would have been about 8 years in Cameroon (1978-1985) and 12 years in Chad (1978-1989), rather than 5 years in Cameroon and 4 years in Chad under the spillover scenario. Under this assumption, the utilization of the technology would have been associated with net benefits of US$ 3 million (rather than US$ 4.6 million) in Cameroon and US$ 6.7 million (rather than US$ 15 million) in Chad. The associated IRR levels would have been 39% (rather than 75%) in Cameroon and 33% (rather than 95%) in Chad. The spillover effect would have been responsible for 36% of the profitability of the use of the technology in Cameroon and 62% in Chad.

6. Tabulated results of the'without spillover'analysis are available from the authors.

This is actually a very optimistic scenario, since in reality the S 35 R&D lags are most likely to be longer than those assumed above for at least the following reasons: NARS in Cameroon and Chad (as in most African countries) do not have the required financial resources, nor do they have the critical mass of scientists to operate as efficiently as their international counterpart, i.e., ICRISAT The spillover effect is more likely to account for larger portions of the profitability of the use of the S 35 technology in the two countries than those estimated under the optimistic scenario above.

Summary and conclusions

S 35 is a product of collaborative research and development by ICRISAT and the Cameroonian and Chadian NARS. Its selection process began in 1978 in India at ICRISAT-Patancheru with the development of F_2, F_3, and F_4 generations of a three-way cross [(SPV 35 X E 35-1) CS 3541]. This culminated, in 1980, in the identification of an F_5 progeny with row number M 91019. This F_5 progeny was sent to collaborating NARS scientists at IAR in Samaru, Nigeria, as an entry in SEPON-1980. At Samaru, a selection was made in 1981 from M 91019 with the designation S 35, S standing for Samaru. The S 35 selection was then sent in 1982 to Maroua, Cameroon, for further evaluation, and testing in the drought-prone northern zones. After four years of on-farm testing at several locations, S 35 was released in 1986 for adoption in Cameroon in low rainfall areas (i.e., 400-800 mm annually). The variety was also sent to Chad in 1986, tested from 1986 to 1988, and released to Chadian farmers in 1989. The total research lag (i.e., the time span from selection to release) for S 35 was about 8 years for release in Cameroon and 12 years for release in Chad. In other words, if each country had had to develop the technology on its own, the research and development lags would have been at least 8 years for Cameroon and 12 years for Chad. But because of germplasm spillover from ICRISAT-Patancheru to Cameroon and later to Chad, the research lags were reduced to only five years in Cameroon and four years in Chad. This availability of germplasm from the international program of ICRISAT has increased the probability of success in NARS research efforts to secure the S 35 technology at reduced costs and to transfer it rapidly to farmers. Consequently, the net benefits and profitability of the use of the technology in the two countries have been substantial, ranging from US$ 4.6 million in Cameroon to US$ 15 million in Chad, representing IRRs of 75% in Cameroon and 95% in Chad.

If each country had had to develop the S 35 technology all by itself, the research and development lags would have been substantially longer; and this would have reduced the economic returns on the utilization of the technology by 36% in Cameroon and 62% in Chad. Germplasm spillover has therefore increased not only the efficiency in the development of the technology but also the economic returns associated with its use. This implies that directors of agricultural research should take greater advantage of spillovers and that future breeding efforts should evolve collaboratively between NARS and their international and regional counterparts.

On-farm surveys were used to track the spread of the S 35 technology in drought-prone areas of Cameroon and Chad and to collect farmers' perceptions. The results of the adoption study clearly show that farmers are substituting S 35 for their traditional varieties. Ten years after its release in northern Cameroon, the variety occupies about 33% of all rainfed sorghum area of the region. In Chad, the S 35 variety occupies 27% of all rainfed sorghum area seven years after its release. Farmers are increasingly substituting the S 35 sorghum for their traditional varieties because the required crop management practices for the S 35 cultivation are simple, familiar, and easy to implement from available family and animal labor. Furthermore, substantial payoffs (high yield and reduced unit production cost) are associated with making these management changes. The major problem with S 35 is its susceptibility to bird attack. This is a consequence of the variety's short duration and sweet grain. Other constraints to adoption described by farmers include soil infertility, nonavailability of pure seed, grain mold, and the high cost of grinding.

Farmers sow more of S 35 when rainfall is perceived to be inadequate. However, because the study areas in Cameroon and Chad have been generally observed to lose an isohyet every 10 years, the cultivation of S 35 could increase if the trend continues. This expected increase in adoption would, however, require availability of seed and market outlets for sorghum and improvement in farmers' income to afford seed and soil fertility technologies. As the FAO/UNDP-supported seed project at Gassi phases out, alternative sources of seed supply in Chad must be secured Similarly in Cameroon, with closing out of the subsidized national seed production program (Projet semencier), more attention should be devoted to the development of an efficient, self-sustaining seed sector. Policy actions, which could provide incentives for private sector participation in the seed sector, should be carefully and seriously considered. Future sorghum breeding efforts in both of these countries should focus not so much on developing new varieties but rather on removing the constraints identified by farmers.

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Resume

L'impact des retombees de recherche sur les ressources phytogenetiques: le cos de la variete de sorgho S 35 au Cameroun et au Tchad. Un objectif important des institutions internationales de recherche agricole est de determiner le degre d'impact eventuel des travaux de recherche sur d'autres regions d'etude. Cette importance est due au fait que la plupart des activites de recherche portent sur les cultures et les zones agro-ecologiques qui se rencontrent dans plusieurs regions du monde. Suivant sa politique, I'ICRISAT a distribue une gamme tres large de materiel vegetal (parents) aux programmes de selection chez les Systemes nationaux de recherche agricole (SNRA) ainsi que chez les industries privees de semences partout dans les regions tropicales serni-arides. D'ou une contribution au developpement plus rapide et rentable des produits finaux utiles par les agences recevant le materiel.

Cette etude evalue les impacts et les retombees secondaires de recherche decoulant de l'adoption de la variete de sorgho S 35, une lignee pure developpee au programme de selection de I'ICRISAT en Inde. La variete a ete avancee au Nigeria et vulgarisee au Cameroun en 1986 et au Tchad en 1989. La S 35 occupe actuellement environ 33% de la superficie totale du sorgho pluvial au Cameroun, 27% au Tchad. Par rapport aux meilleurs varietes traditionnelles a travers toutes les localites d'etude au Cameroun et au Tchad, la S 35 donne 27% plus de rendement (grain) et permet de reduire le cout unitaire de production de 20%. Ces impacts au niveau du champ paysan se revelent plus importants au Tchad ou le gain de rendement est 51% plus eleve et la reduction du cout est 33% plus importante. La valeur nette actuelle des benefices decoulant des retombees secondaires de la recherche sur S 35 dans la region africaine a ete estimee a US$15 millions au Tchad et US$4.6 millions au Cameroun, ce qui represente des taux internes de rentabilite de 95% au Tchad et de 75% au Cameroun. Ces impacts ont ete evalues dans l'optique des systemes nationaux de recherche. Une decision consciente a ete prise done pour n'inclure que les couts associes aux institutions nationales de recherche et de vulgarisation. Toutes les autres depenses relatives a la recherche et au developpement de la S 35 et encourues en Inde et au Nigeria ont ete traitees de "couts noyes", c'est-a-dire les couts que Ton aurait subis en tout cas sans les retombees secondaires. Si chaque pays avait eu a developper tout seul la S 35 et les pratiques associees de gestion, les delais entre la recherche et la vulgarisation de la nouvelle technologie auraient ete bien plus longs. Par consequent, les impacts eventuels auraient ete moins importants. Dans le but de realiser le developpement et le transfert plus efficaces de la technologie du sorgho dans la region, les .actions futures en matiere de la politique et la recherche devraient tirer une plus grande benefice des retombees secondaires de recherche a travers la collaboration, la communication et les reseaux plus efficaces entre les institutions de recherche nationales, regionales et internationales.

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 16 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 United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), and the World Bank.

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