

## ECONOMIC IMPACT OF THE COMMODITY RESEARCH NETWORKS OF SAFGRAD

### INTRODUCTION:

SAFGRAD has served as an intermediary between the IARCs and the NARS. In the international research system the IARCs are responsible for strategic research. Since one principal characteristic of biological and chemical research is its location-specific nature, the NARS can then concentrate on the applied or adaptive research. In an effective partnership, there would be substantial interaction between the two types of research institutes. Historically, the NARS took technology concepts and material from the IARCs. The NARS then tested and adapted the material and concepts and then passed the products on to seed producers or the extension service.

The problem of this impact evaluation is not to evaluate the returns to agricultural research. It is well known that these returns are extremely high both for the developed countries and for the developing ones including Sub-Saharan Africa (Karanja, 1992; Ahmed and Sanders, 1991). The problem here is to assess the impact of an intermediate agency. One principal function of SAFGRAD has been to help set up research networks to facilitate the transmission of information and material between the NARS. Another basic function of SAFGRAD was to help build up the capacity of the NARS to do applied research and to successfully interact with the IARCs.

This paper will be concerned first with describing the impact of new technologies for the four principal food crops of the semi-arid tropics. The development of some of this new technology precedes SAFGRAD; however, one of the main roles of SAFGRAD presently is to facilitate the movement of new germplasm and new technology concepts between countries. It is also important to stress the dynamic nature of African agriculture by reviewing the extent of new technology introduction. The second objective of the paper is to estimate the economic impact of several new technologies directly associated with SAFGRAD research and/or information sharing in the networks.

SAFGRAD facilitates communication between the IARCs and the NARS but its principal function is to empower the NARS to take on a larger role in the scientific system. In the past decade the NARS have substantially expanded the training and scientific capacity of their personnel and many have successfully produced and helped to extend new technologies on to farmers' fields.

SAFGRAD has been in existence almost 15 years. During that time there has been a substantial increase in the capacity of the NARS. It is a popular misconception that there has been little progress in developing new technologies for the food crops of concern to the SAFGRAD program.

There have been substantial successes with maize and cowpeas. There have also been new cultivar introductions of sorghum. But the changes have been less dramatic than in the cases of maize and cowpeas. This report documents first the introductions of new technologies to illustrate the dynamic nature of these agricultural systems.

The second objective is to describe and evaluate the impact of SAFGRAD, especially the performance of the networks. The most tangible and measurable gains to a research network are those technologies that make it through the IARC and NARS systems and that are adopted by farmers. Networks help give the NARS access to new germplasm and technology concepts and help refine their critical ability to pick and choose those components which will be of most use to them.

A critical role of SAFGRAD is to facilitate spillover. Spillover is the movement of technologies between research systems and countries. Scientific interaction between researchers in developed countries goes on at such a high and regular level through journals and scientific meetings as well as frequent interaction with colleagues that few scientists even think about it. In Sub-Saharan Africa this interaction is much more expensive and difficult. Hence one of the principal functions of SAFGRAD has been to finance and to facilitate these contacts between all levels of the NARS and between the NARS and the IARCs.

As illustrations of the economic impact at the farm level and the spillovers from research, the performance of three SAFGRAD commodities will be considered. The research strategies for all three were broadly similar. In all three commodities breeders looked for earliness and for resistances to different diseases, insects, and to a parasitic weed, *Striga*.

Finally, some comparisons will be made between the performance of the research systems for maize and cowpeas with those for sorghum and millet. For a number of reasons important to future research performance, maize and cowpeas have been much more successful than sorghum and millet.

## FOOD CROPS OF THE SEMI-ARID ZONE:

The SAFGRAD program and its predecessor programs were a response to the Sahelian droughts. The first major recent drought was 1968-1973 and the next one, extending over a wider area in Sub-Saharan Africa, was in 1982-84. Besides these acute droughts there has also been a chronic drought in the Sahel, as rainfall after the high rainfall period of the '50s and '60s was one standard deviation below the long-term normal from 1968 through the '80s (Glantz, 1987, p. 39). The basic concern of the SAFGRAD program was to increase the productivity of the food crops of the region to approach food self-sufficiency so that in the future the food supply would be less sensitive to climatic disturbances. Unfortunately, in both the '80s and the '90s civil wars and other domestic disturbances have been as important if not more important than climatic factors in disrupting food supplies.

The basic food crops of the semi-arid region are sorghum, millet, maize, and cowpeas. Research programs were already underway in three major IARCs, ICRISAT, IITA, and CIMMYT, on these commodities. SAFGRAD then sought to do complementary activities to accelerate the process of moving new technology from the research stations to farmers' fields. The principal emphasis of SAFGRAD has always been to build up the capacity of the NARS.

With the decline in the consumption per capita of sorghum/millet due to the substantially increased consumption of imported rice and wheat, concern has been raised over the commodity choices. Wheat and rice have two advantages over the traditional and predominant cereals of the semi-arid region: First, there has been substantial investment in preparation and processing of these two cereals in developed countries; hence, the time requirements for food preparation by women in urban areas of Africa are substantially reduced as compared with the traditional cereals. Secondly, overvalued exchange rates and economic policies to benefit urban consumers have been widely practiced in Sub-Saharan Africa and both end up giving price advantages to food imports over domestically produced cereals. There may also be a third factor in that higher-income people in Africa prefer wheat and rice over sorghum and millet. Unfortunately, in the econometric studies to date this possible taste-preference factor has not been separated from the convenience factor. Moreover, even with the decline in consumption of millet and sorghum, they are still the predominant food group in Sub-Saharan Africa and are expected to continue in that position for a long time (Fig. 1). Presently, there are 8.5 and 10 million ha of sorghum and millet, respectively, in West and Central Africa. In Eastern Africa, where maize is the principal staple and most important crop, there are 6 and 2 million ha of sorghum and millet. So these traditional cereals continue to be very important crops for farmers' incomes and consumers' welfare.

Maize is the most important food crop in Eastern and Southern Africa. In West and Central Africa maize performs an important supplementary role in the food supply. In the drier, Sudanian climatic regions the early maize varieties become available before the sorghum and millet, thus providing food before the main cereal harvest. In Central Africa maize provides a supplementary source of calories and protein to the root crops. The root crops, especially cassava, generally have a very poor balance of nutrients. In spite of maize's lesser importance in West and Central Africa, there has been a substantial increase in production here in the last two decades and some productivity growth (CIMMYT, 1990, p. 10).

Approximately, two thirds of the world's cowpeas come from West and Central Africa, where they are extensively grown, predominantly in association with the cereals. They add protein to the diet and are especially important in the sandy-dune soils of the drier regions in association with millet. Yields in association in general are low, 100-400 kg/ha. Cowpeas are found all over these two regions but production is concentrated in Nigeria and Niger.

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## EARLY MAIZE IN WEST AND CENTRAL AFRICA:

There have been notable successes in maize breeding and diffusion in Southern Africa. A famous hybrid was developed in colonial Zimbabwe, SR-52, and later diffused throughout Southern Africa. Earliness for drought escape and hybrid vigor were two of the most important characteristics of this successful introduction. The national Kenyan breeding program also followed these same concepts of developing early hybrids with region-specific adaptation. Maize area in hybrids increased from 2% in 1960-64 to 64% in 1985-88. In the latter period there were almost a million ha in hybrid maize in Kenya. The average rate of return to this research was 68% (Karanja and Okech, 1992). This Kenyan case is a good example of the way researchers can take the basic concepts from successes of other researchers and then adapt them to the location-specific requirements of their region. This scientific interaction or spillover of concepts and material or germplasm is a fundamental principle of success with scientific research.

Maize is much less important in the production and food systems of West and Central Africa than it is in East and Southern Africa. Only 15% of the maize on the continent is produced in West and Central Africa. In this region maize is cultivated on 5 million ha with about 74% for human consumption (Badu-Apraku, 1992b, p. 3). Here 50% of the maize is produced in the northern Guinea savanna climatic region and 20% in the much drier, Sudan region (SAFGRAD, 1993, p. 10). In the Sudanian region maize is primarily produced in the small compound areas around the households where fertility and water retention are increased by the dumping of household refuse. These are generally very small areas, 0.1 to 0.2 ha, but maize plays a critical part in household consumption by becoming available before the harvest of the millet and sorghum during the "soudure" or hungry season.

The SAFGRAD-supported research program in maize (implemented by IITA) has emphasized earliness and extra-earliness for the Guinean and Sudanian regions. Earliness is a method of drought escape. In SAFGRAD-I, IITA collaborated to move outside of its mandate area for maize of the humid and semi-humid tropics into the semi-arid zone. Moreover, the breeding and other supplementary research for extra-early maize designed specifically for the Sudanian regions is being undertaken only by the Maize Network. The IARCs (IITA and CIMMYT) are not providing material for this maturity group. This extra-early material is an excellent example of the increasing scientific independence of the NARS in the network. As they produce more of their own new material, they can use the IARCs for ideas, concepts, and techniques.

Since maize cultivars are planted in areas with higher rainfall or with better water-holding capacity, organic or inorganic fertilizers are generally used, especially nitrogen. Agronomic technologies to increase soil nutrients are expected to have a high return complementing the breeders' new cultivars. Once improved cultivars and agronomy are available, concern with the profitability

of the farmers' environment becomes a very important consideration in evaluating the impact or lack of impact of new technologies.

Table 1 combines the CIMMYT data on the diffusion of improved maize varieties in West and Central Africa with the names of the new NARS cultivars and other new technologies. Some of the new varieties and the other technologies are associated with the SAFGRAD-supported research and networking.

For West and Central Africa there has been successful introduction of new cultivars, including some with earliness, in Ghana and Cameroon. In Ghana approximately 55% of the maize area was in improved cultivars in 1992. (Badu-Apraku, personal communication). Some, such as Abeleehi, have been developed locally, tested, and extended by an excellent local maize team. Others, such as the early SAFITA-2, were part of the SAFGRAD network exchange and have been successfully introduced. In Ghana maize production increased from 265,000 tons in 1982 to 932,000 tons in 1991 (Table 2).

In Cameroon the intermediate maize with streak resistance, TZB/TZB-SR, covers 15% of the maize area, 75,000 ha, with an estimated annual production of 90,000 tons. For the semi-arid region of Cameroon, where sorghum and millet production predominate, the introduction of new early maize cultivars has resulted in a doubling of maize area to 35,000 ha with an estimated 1,000 families producing these cultivars (SAFGRAD, 1993, p. 7). In Burkina Faso new maize cultivars occupy 65% of the maize area or 133,900 ha (SAFGRAD, 1993, p. 7).

The introduction of new maize cultivars combined with other new agronomic practices, especially chemical fertilizer and higher densities, has occurred at a rapid rate in the last decade in the Guinean savanna and in small areas of the Sudanian zone. However, especially for the latter zone, maize is a minor crop and serves mainly as food during the hunger period while farmers are waiting for the harvest of the major cereals, sorghum, and millet.

Table 1. Maize Production Trends and Adoption of Improved Maize Varieties in some Countries of West and Central Africa.

Country	Production (1990)		Maize Area % of Cereals 1986/90	Percent of Total Maize Area Planted to Improved Varieties in 1988	Maize Varieties Exchanged Through Network and Released by NARS
	IN-1000 ha	IN-1000 tons			
BENIN	485	455	73	41	TZB, TZB-SR, TZESR, Poza Rica 7843-SR, PIRSABACK 7930-SR and DMR-ESRW.
BURKINA FASO	221	257	8	27	TZEE-WSR, TZEE-YSR, SR 22, MAKa, 8330-SR, 8321-18, TZESR-W and SAFITA-2.
CAMEROON	440	600	47	18	CMS8710, TZPB-SR, TZB-SR, Mexican 17E, SAFITA-2, CMS 8806, Pool-16-DR, CMS 8501 and CMS 8507
CHAD	45	31	NA	NA	CMS 8501, CMS 8507,
COTE D'IVOIRE	670	530	49	10	TZSR-Y, Pool-16DR, Maka
GHANA	567	750	47	43	Okomasa, Dobidi, Aburotia, Abelehee, SAFITA-2, Kawanzie, Golden Crystal, La Posta and Dorke-SR.
GUINEA CONAKRY	94	108	NA	NA	Farak 88 Pool 16-DR, DMR-ESRY, TZEF-Y, CSP, EV 8420-SR, Ikenne 83, TZSR-Y.
MALI	126	228	20	36	SAFITA-2, TZESR-W, Golden Crystal, TZPB-SR, and TZEF-Y.
MAURITANIA	4	3	NA	NA	Maka, CSP Early, SAFITA-2.
NIGER	15	80	NA	NA	EV8431-SR, TZER-W, MAKa, JF de Saria
NIGERIA	1500	1600	14	40	TZB-SR, TZPB-SR, TZESR-W, DMR-ESRW, DMR-ESR-Y, EV8418-SR and Pool 16 DR.
SENEGAL	105	110	5	100	Maka, Tocumen 7835, Pool 16 DR.
TOGO	255	245	44	15	Ikenne 8149-SR and EV8443-SR.

Source: Taken from SAFGRAD, 1993, p. 41. The references used there are:

(1) Impact Assessment Study - Synthesis of primary data report of Maize Network May, 1991.

(2) 1989/90 CIMMYT World Maize, Facts and Trends.

(3) J.M. Fajemisin, 1991, Outline of National Maize Research Systems in West and Central Africa.

## RETURNS TO NATIONAL AND SAFGRAD PROMOTED RESEARCH IN MAIZE:

New maize cultivars have been most successfully introduced in Guinea savanna regions. Here there is sufficient rain in most years to reduce the risks of fertilization. Also in these regions there have often been successful breeding and agronomic improvements with cotton. Hence, there is a research establishment that has worked with farmers and released new technologies. Moreover, farmers have seen the effects of chemical fertilizer and pesticides and markets have been established for these inputs. Guinea savanna successes with maize include northern Ghana, Nigeria, Cameroon, southern Mali, and Burkina Faso.

Looking at one particular country program in more detail, the net social benefits to the national program are compared with the benefits of the introduction of the early maizes in Ghana (Table 2).

**Table 2. Areas and Benefits of Improved Maize Cultivars in Ghana, 1982-1991.**

Year	Maize Production (000 m.t.)	% Area in Improved Cultivars	% Area in SAFGRAD- Improved Cultivars	Net Social Benefits of National Program	Net Social Benefits of SAFGRAD Program
				(Million dollars - 1991)	
1982	265	20		8.3	
1983	141	20		4.8	
1984	380	35		36.4	
1985	394	30		22.7	
1986	559	30	2.0	22.7	0.4
1987	558	35	3.0	20.4	0.4
1988	600	40	3.5	46.8	0.8
1989	750	57	3.5	154.1	1.1
1990	850	50	4.0	72.5	1.4
1991	932	55	4.0	83.6	1.4

In the decade maize production approximately quadrupled. The area in improved cultivars increased from 20% to 55%. The net social benefits deduct the additional input costs but do not deduct the costs of research and extension. They range from 4.8 to 154 million dollars per year. These are substantial benefits for the Ghanaian NARS. When the research and extension costs are also considered, the internal rate of return to the public investment in the national maize program

is 74% (see Appendix B for some details on this calculation; the tables are available from the author). This is an excellent return on a public investment.

SAFGRAD-associated early cultivars, including SAFITA-2, Kawanzie, and Dorke SR — a streak-resistant successor to SAFITA, made their appearance in the second half of the decade. Over the six years since they have been introduced, the net social benefits have ranged from \$400,000 to \$1.4 million per year. Some research and extension costs need to be deducted. However, this is already a substantial return on one research project and its impact in one country. As was previously shown in Table 1, new maize cultivars are becoming widely adopted in Sub-Saharan Africa.

This type of network and SAFGRAD benefits for earliness can be summed over a large number of regions mentioned above and in the cultivar description of Table 1. A recent study of the introduction of new maize cultivars in the high-rainfall Guinean region of Mali estimated a rate of return of 135% (Boughton and de Frahan, 1993). The Sahelian as well as the coastal countries are able to benefit from the new maize cultivars. But the major impact is still in the Guinean zones of both the coastal and Sahelian countries.

#### **A SIMILAR STORY FOR COWPEAS IN WEST AND CENTRAL AFRICA:**

The cowpea experience is very similar to that of maize. There has been a concentration on earliness and substantial successes in the introduction of new early cultivars in West and Central Africa. Unfortunately, there are fewer estimates of the extent of diffusion of these new cultivars than in the case of maize. The principal production areas are Nigeria and Niger with approximately one-half of world cowpea production (SAFGRAD, 1993, p. 42).

As in the maize case, breeders also worked on other resistances especially to *Striga*, aphids, thrips (field insects), bruchids (storage insects), and diseases. Agronomic research has shown the high return to phosphorous fertilizer in combination with new cultivars (SAFGRAD, 1993; also Shapiro et al., 1993). A devastating problem for cowpea is storage insects. The agronomic and the storage components of the new cowpea technologies are critical additions to the breeding search for new cultivars.

In Ghana a new cultivar, Vallenga, released in 1987, has been introduced on more than 20,000 ha in the north, raising farmers' yields to approximately one ton. In higher-rainfall southern Ghana, Asontem is cultivated on 29,000 ha. Still other new cowpea cultivars are being introduced in the savanna regions. As with the improved cultivars of maize, the introduction of new cowpea cultivars is associated with other new technologies, especially chemical control of insects and monoculture row planting (Dankyi and Dakurah, 1992, p. 4). New early cowpeas have also been successfully

introduced and are now found in large areas of Burkina Faso, Mali, Senegal, and Nigeria (SAFGRAD, 1993, p. 8).

### **BENEFITS OF COWPEA RESEARCH FOR BURKINA FASO AND MALI:**

Even though the area and production of cowpeas is not very large in these two countries compared with Nigeria and Niger, this crop is very important for improving nutrition and ultimately for improving the cropping system by providing the fertility and other systems interactions between cereals and grain legumes. Moreover, as with maize, the cowpea-breeding work implemented here since the early '80s by IITA represents a movement north by IITA outside of its mandate area of the humid and semi-humid tropics. SAFGRAD was instrumental in getting IITA to work on the specific problems of the semi-arid regions in both maize and cowpeas. The yield gains with maize have been much greater to date due to the much higher use of chemical inputs associated with the new maize cultivars. However, the economic effects of maintenance research are substantial, as will be seen below.

Diffusion of the new cowpea cultivars in these two countries has been pervasive and this by itself is an important success story (see Tables A-3, A-4, and A-5 in Appendix C for documentation of this diffusion process in three different climatic zones of these two countries). Grain legumes are a vital part of the production system but are very difficult to produce in the tropics. Besides the increased incidence of droughts since 1968, *Striga*, field and storage insects, and several diseases are all serious production problems. The benefits to this cowpea research are the gains to maintaining yields over time in an increasingly difficult environment. When rust-resistance breaks down in the U.S., the new wheat cultivar has a substantial effect on farmers' welfare by maintaining yields. Cowpea research has had this same maintenance effect in Burkina Faso and Mali. Yield benefits are calculated, assuming that the new cultivars prevent farm-level yields from falling by 100 to 200 kg/ha. Production is predominantly in association.

**Table 3. Production and Social Benefits From the Introduction of New Cowpea Cultivars in Burkina Faso and Mali.**

Year	Production (1,000 m.t.)	Social Returns (Million U.S. Dollars)	
		25% Yield Decline	50% Yield Decline
1984	41.0	0.8	1.8
1985	103.9	1.9	4.4
1986	90.8	2.6	6.3
1987	46.4	2.5	6.2
1988	104.7	4.0	10.0
1989	78.7	2.9	7.5
1990	59.4	3.8	9.7
1991	80.9	4.8	12.3

So the annual economic benefits to maintaining farmers' yields range from \$800,000 to \$4.8 million, with the most conservative assumption about yield declines in the absence of the new cultivars. With the more realistic assumption of a 50% decline in cowpea yields in the absence of the new cultivars, the social benefits to research range from \$1.8 to \$12.3 million per year. These are the benefits to society resulting from this cowpea research promoted by SAFGRAD and implemented by IITA. Presently, the research and extension costs are being put together to calculate the rate of return to this investment.

#### **SORGHUM/MILLET IN WEST AND CENTRAL AFRICA:**

Even though these two crops are more important in the region, there has been less diffusion of new material onto farmers' fields than in the case of maize and cowpeas. Maize and cowpeas have many production problems and are more difficult to grow than the hardier, more resistant sorghum and millet. For maize, farmers know that they have to use higher inputs to take advantage of new material. Generally, chemical fertilizer is employed with the improved maize cultivars.

Both maize and cowpeas are high-value crops produced on small areas, so the risk of price collapses in good rainfall years is less than in the case of sorghum and millet. These price collapses

are a recurrent phenomenon with these two basic staples of sorghum and millet. In poor rainfall years, prices become very high until food aid or imports are obtained. Then in good rainfall years prices collapse. Recurrent drought, food aid, and price collapses all discourage farmers from investing in new technologies for sorghum and millet production.

To obtain the gains from new cultivars of millet and sorghum, higher input use will be necessary. This higher input use is riskier for sorghum than for maize since sorghum is grown on poorer soils and is subject to more price variation. Also on most of the soils on which sorghum is grown, increased use of water-retention methods will need to complement the use of increased chemical fertilizer in order to increase the returns and reduce the risks of the farmers' expenditures on chemical fertilizer (Sanders et al., 1990). Thus, there are more new technology components as well as more price fluctuation for sorghum than for maize.

In spite of these greater requirements for new sorghum technology introduction, there has been some progress, especially in the Sudanian region. For example, in northern Cameroon S-35 has been successfully introduced. This Indian non-photoperiod sensitive, 90-day cultivar was found to be locally adapted in northern Nigeria by Rao. He made seed available for northern Cameroon and S-35 was tested in the on-farm trials supported by the Cameroon National Cereals Research and Extension Project and was successfully introduced into northern Cameroon (Johnson, 1987; Kamuanga and Fobasso, 1992).

In northern Ghana and Togo and in the Manga region of Burkina the *Striga*-resistant Framida has been introduced (SAFGRAD, 1993, p. 31). The sorghum area in improved cultivars in Ghana increased from 10% to 17% and their importance in production increased from 13% to 24% over the period 1982-1991 (unpublished data from the Ghanaian national program). In a farm survey in northern Ghana, 20% of the farmers planted improved sorghum cultivars and half of this was in Framida. Even though farmers identified soil fertility as a major constraint, 84% raising red varieties, including Framida, do not use fertilizer. In contrast in the same region, 88% of the farmers raising white (improved) maizes did use fertilizer (Dakurah et al., 1992, pp. 5, 9, 10).

In northern Nigeria several cultivars associated with new industrial uses for sorghum have been successfully introduced. Farafara was introduced for its taste characteristics in a composite bread with up to 10% sorghum. SK-5912 has been selected for its malting quality. There is also increasing interest among researchers and development personnel in Cameroon in increasing the industrial demand for sorghum for both bread and beer. To stimulate local cereals and industrial utilization, Nigeria has erected trade barriers to imported cereals. Cameroon has not imposed these barriers and is presently looking for alternative methods to increase the interest of local industries in these uses for sorghum (NCRE, 1989).

Finally, in Mali there is important ongoing collaborative research between entomologists and breeders on the headbug complex. This complex appears to be one of the critical constraints to introducing high yielding sorghums in the Sahel. Major research efforts are also underway in the networks and in the INTSORMIL CRSP on *Striga*, anthracnose, and drought tolerance.

## **RETURNS TO NATIONAL AND SAFGRAD PROMOTED SORGHUM RESEARCH IN WEST AND CENTRAL AFRICA:**

In large-scale, on-farm testing of new technologies by the National Cereals Research and Extension Project (NCRE) of Cameroon there was a surprising result in 1984. In this drought year the yields of S-35 were almost double the local and the other new varieties (Kamunga and Fobasso, 1992, p. 22; Johnson, 1987, p. 657). Trials continued another three years. In these normal and good rainfall years after 1984, the yield advantage to the 90-day, non-photoperiod sensitive S-35 was minimal. Nevertheless, when it was released in 1986, farmers began rapidly introducing this cultivar into the mix of cultivars of different season length that they employ.

The NCRE final report (p.108) estimated that there were 5,000 ha in S-35 in the Extreme North province. With another 5,000 ha in the North province, this would be approximately 10,000 ha in 1991. This is a conservative estimate of the extent of diffusion. Sorghum production is concentrated in these two provinces in Cameroon. Another diffusion study estimated that 8.7% of the sorghum area in the center north zone (Nord and Extreme-Nord) was in S-35. This 8.3% includes approximately 64% of the sorghum producers (calculated from the estimated 210,000 farmers in the survey area and estimates of 330,000 sorghum producers in Cameroon (see Kamunga and Fobasso, 1992, p. 1). According to this estimate, there would be approximately 26,000 ha in S-35 in 1990. From these two point estimates of diffusion, 26,000 ha in 1990 and 10,000 ha. in 1991, two series of estimates of diffusion over the period 1986-1992 were made. These were then utilized to estimate the social benefits of the new technology introduction (Table 3. For the technique used to estimate the changes in consumer and producer surplus, see Akino and Hayami, 1975).

**Table 4. Diffusion and Social Benefits of the Introduction of S-35 Into Cameroon.**

Year	DIFFUSION ESTIMATES (1,000 ha)		SOCIAL BENEFITS (1,000 U.S.\$ - 1990)	
	Conservative	Optimistic	Conservative	Optimistic
1986	0.65	0.65	7.6	7.6
1987	4.00	5.00	13.0	17.0
1988	6.00	10.00	36.0	71.0
1989	8.00	15.00	41.0	91.0
1990	10.00	26.00	50.0	131.0
1991	10.00	28.00	288.0	831.0
1992	12.00	30.00	57.0	144.0

In 1992 S-35 was produced on 12,000 to 30,000 ha in the drier Sudanian regions of Cameroon. This introduction reduced the drought risk and encouraged some of the farmers to utilize higher inputs. After seven years of diffusion, the social benefits ranged up to \$288,000 per year in the conservative estimate of diffusion and up to \$831,000 per year with the more optimistic scenario. In either case, these are good initial successes in a difficult zone to improve farmers' productivity and welfare.

This reduction of drought risk is very important in this subsistence cropping system with an average farm size of 2.5 ha. In these low rainfall zones, the optimal technology-development strategy may be to raise expected incomes by reducing the income loss in adverse rainfall years. S-35 has been very successful for this type of strategy.

Except for poor rainfall years, the yield gains from S-35 were minimal. Two factors responsible for the lack of yield increase in normal and good rainfall years were: Earliness gives drought escape but reduces the potential of the plant to respond to better growing conditions. Since there were substantial drought problems in the '80s, the earliness of S-35 has been much appreciated. However, in good rainfall years there was no advantage to S-35 over local cultivars. Early material in semi-arid environments often has insufficient time in the field to respond to higher input levels. Secondly, in contrast with the new maize cultivars discussed above, there has been little increased fertilizer use accompanying the introduction of S-35, except where sorghum was rotated with cotton and could take advantage of the residual effect from the cotton fertilization. Hence, the new cultivar only joins the farmers' portfolio collection of early, intermediate, and late cultivars without chemical fertilizer.

Many farmers are now utilizing S-35 on small areas. However, unless new varieties are combined with higher purchased, chemical-input levels, yield gains will be minimal. To raise yields substantially, as in the maize case in the Guinean zone, higher levels of chemical inputs will be necessary. Future sorghum yield gains will require chemical fertilizer and probably some improved intermediate and late cultivars and increased use of water-retention measures. Elimination of the sorghum-price collapse in good rainfall years by encouraging demand growth for alternative uses would increase expected incomes and encourage new cultivar and fertilizer diffusion.

The success with S-35 also helps indicate the future research agenda. The earliness and the white, low-tannin, "sweet" grain make the taste appreciated by farmers and by birds. S-35 is also very susceptible to *Striga*. Presently, there is substantial sorghum research activity on *Striga* in the networks and in the sorghum CRSP.

Introduction of S-35 has been concentrated in the Sudanian zone since in higher-rainfall regions earliness can be a disadvantage. Late rains can cause serious problems with grain molds. For the Guinean region there has been continued work with the later S-34. As another example of the spillovers of new cultivars, S-35 has been introduced on 15,000 ha in Chad (NCRE, 1991, p. 108).

## **SORGHUM/MILLET IN EAST AFRICA:**

There are two very important sorghum producers here, Sudan and Ethiopia. Both have had sorghum-breeding programs over several decades and have produced new cultivars. The first commercially successful sorghum hybrid in Sub-Saharan Africa, Hageen Dura-1, is now produced on 12% of the sorghum area in the Gezira irrigation scheme and is expanding rapidly there. (Nichola, 1993). The Gezira in the Sudan is one of the largest irrigation projects in the world. Also in the Sudan SRN-39, a variety resistant to *Striga*, has been reported as being produced on 50,000 ha in the mechanized drylands.

In both Sudan and Ethiopia, with collaboration from ICRISAT and SAFGRAD, integrated control programs have been developed for *Striga* including tolerant varieties, agronomic practices, fertilizer and herbicide use. In Ethiopia several new sorghum cultivars have been introduced including Gambella 1107. Again illustrating the spillover effect of scientific development, Gambella was also released in Burundi where this white sorghum is highly appreciated for food and for composite flour. Later Gambella was introduced in Burkina Faso as E 35-1.

In Kenya a new variety, Kat 369 has been found to be suitable for both composite bread and for other confectionery products. New varieties for the brewing industry have been identified for Burundi and Rwanda (SAFGRAD, 1993, pp. 6, 7). Hugh Doggett's sorghum cultivars from his

Ugandan research in the '50s and '60s have been introduced into Ethiopia, Kenya, Tanzania, and Uganda. His brown-seeded cultivars, including Serena and Seredo, have been very well appreciated where bird problems are serious. In much of East Africa the quella bird can be a serious pest.

In Eastern and Southern Africa (with the exception of Sudan and Ethiopia) in the colonial and post-colonial periods there had been much more research effort on maize than on sorghum. The development of early maizes has enabled drought escape and thereby facilitated the continuing substitution of maize for sorghum and millet. Maize is generally preferred for its taste and some nutritional advantages; however, the continuing substitution of maize and the previous failure to invest in sorghum/millet research makes many of the semi-arid regions of East Africa even more susceptible over time to climatic variation. Sorghum/millet have greater tolerance to climatic and soil-fertility stress than maize, but it is necessary to take advantage of these inherent favorable characteristics by continual improvements in breeding programs. More research and policy efforts need to be focused on sorghum/millet for the semi-arid regions in the countries south of Sudan and Ethiopia.

## EVOLUTION OF THE NARS IN THE EIGHTIES:

One principal concentration of the networks and of the SAFGRAD research program in Phase I (1978-1986) was earliness for drought escape. Besides this characteristic, the research programs in the NARS looked for resistances to different diseases, insects, and the parasitic weed, *Striga*. In the '70s and '80s the IARCs had gathered large gene pools and substantially developed screening methodologies for identifying resistant germplasm so they were able to provide that expertise and their commodity-based organizational model to the NARS in the '80s.

In the '80s there was a gradual evolution of commodity programs in the NARS. Trained national scientists had returned with M.S. and Ph.D. degrees in the '70s and '80s. Moreover, in many countries financial resources became available in the '80s to bring these scientists together into commodity research teams and to do on-farm technology testing. These programs provided additional resources and incentives to national scientists. One criticism of these programs was the frequent dependence upon large numbers of expatriate scientists rather than on larger investment programs for national scientist academic training.

By the end of the '80s, the NARS were making larger inputs into the research system. An increasing percentage of the material entering into the regional cultivar and on-farm trials was coming out of the NARS (SAFGRAD, 1993, pp. 32, 33, 39, 43, 44). Moreover, the networks began utilizing their different NARS member research systems for specialization in specific research

problems identified as being principal constraints in their country programs. Lead countries for specific research areas, such as *Striga* or drought tolerance, were identified as the networks tried to obtain the comparative advantage from between-country research specialization (SAFGRAD, 1993, pp. 24, 26, 28, 30). But all countries shared germplasm and workshops so they could all take advantage of gains made in the other NARS as well as in the IARCs. Thus, in the '90s the NARS were producing new germplasm and also new concepts, especially on the applied side of technology development, such as the integrated control methods for *Striga* developed in Sudan and Ethiopia.

In the '90s the networks had developed regular interchanges of material, workshops, and directors' meetings. Among the stronger NARS there was a new pride in the system as the new technologies (new cultivars and improved agronomy, especially higher use of chemicals) were finally moving onto farmers' fields. However, only in maize and cowpeas has the successful diffusion been clearly documented (CIMMYT, 1991; Coulibaly, 1987).

Successful agricultural research systems deserve to be financed by their own governments. In developed countries farmers and other beneficiaries from technological change pressure legislatures to support public research institutions. In developing countries farmers often have little influence on the public funding process. Hence, it is very important that research institutions monitor and document well the diffusion process to demonstrate to public policymakers the very high returns to the research process.

In the '90s, with increasingly scarce donor resources and a popular misconception that agricultural research has not been successful or performed well in Sub-Saharan Africa, agricultural research institutions, both the NARS and the IARCs, need to make sure that their impacts are accurately measured and that the size of these social benefits is widely known. Donor financing for research systems in developing countries is expected to become increasingly tied to the willingness of national governments to support their own NARS.

## **FUTURE RESEARCH PRIORITIES:**

The commodity choices of SAFGRAD still appear to be the most important crops for human nutrition in semi-arid regions. Substantial gains in productivity for maize and cowpeas are beginning. Sorghum and millet are more difficult but there should be important productivity gains for these commodities in the next decade. Building up functional commodity programs and strengthening NARS are long-term commitments that need to be continuous. The networks are now progressing well and are increasingly developing self-confidence and becoming more assertive in the international research system. Solid research achievements are beginning to occur and the networks

are beginning to enable the NARS to achieve more self-confidence and to further take over their research system choices. This empowering of the NARS is an important development and needs to be solidified.

Another important choice for the donors in the '90s is on which end of the research system to concentrate their resources. In 1992 the CGIAR system increased its number of supported institutions but did not increase its budget. Hence, there is presently substantial economic pressure on the IARCs. The argument is being made that the pool of available scientific knowledge is now being used up as the NARS have been increasingly successful at utilizing IARC material and concepts and the NARS are increasingly producing their own materials. At some point it will become important to make basic investments in the IARCs and elsewhere to produce a body of concepts and strategic research from which the NARS can continue to draw in the future.

In developed countries there is increasing concern with the exhaustion of the yield gains from traditional breeding and agronomic techniques even when the new cultivars are combined with high levels of conventional inputs. There is increasing research, popular discussion, and private investment in bio-technology. But even for developed countries, most of the yield gains for the basic crops over the next decade will continue to come from extensions of the conventional breeding techniques rather than from bio-technology (Ruttan, 1991, p. 402). Moreover, in Sub-Saharan Africa, substantial gains are still possible from increasing input levels and from adapting known research techniques including breeding. Being on the frontier or cutting edge of new technology production is extremely expensive for developed-country institutions. There will be gains to developing countries in adapting these bio-technology innovations but this is still a problem to be faced after the year 2000.

The other end of the research system is what happens to the new technologies after they have been successfully adapted or developed by the NARS. Private industries are generally necessary to produce seeds, distribute fertilizer, and market the product. Good extension services, such as the Global 2000 program, have been very successful at accelerating the introduction of new maize cultivars in Ghana and Hageen Dura-1 in the Sudan. Many African countries badly need basic improvements in infrastructure (roads, ports, communication networks) to reduce marketing costs of products and inputs and to improve information flows to farmers and consumers. The successes of the NARS in adapting new technologies and in building themselves up now serve to focus attention on the inadequate previous investments by both the private and the public sectors in developing the facilities and the institutions needed to support the NARS by accelerating the diffusion of new technologies from the experiment stations onto farmers' fields. Over the next decade these are expected to be the high payoff investments for the donors in Sub-Saharan Africa. Finally, the most important investments to facilitate technological change will need to be made by developing

countries themselves in rapidly improving the education and health of their farmers and the rest of their population.

## CONCLUSIONS:

The network programs have facilitated the spillover and the successful introduction of the semi-arid food crops, especially early maize and cowpeas. There has been rapid introduction of both maize and cowpeas in the higher-rainfall Guinean regions, such as northern Cameroon, northern Nigeria, and northern Ghana. Here increased chemical utilization on maize and cotton has been highly profitable so the soil fertility environment for new cultivars has been much more favorable than in the harsher Sudanian region. The risk of inadequate water availability during the growing season in the Guinean region is also less than in the Sudanian zone.

In the Sudanian zones the same breeding techniques were also applied. A new category of extra-early maizes was developed and introduced principally on the small compound areas with higher fertility. Even though the area in these new maizes is small, this increased maize production plays an important part in family nutrition at a time of food shortage before the harvest of the other cereals. The SAFGRAD-I project (USAID funds) specifically funded the breeding research for earliness and enabled IITA maize researchers to expand outside their mandate area for maize into the semi-arid tropics. Moreover, the earliness combined with the other resistances became a major success story for maize.

Cowpea successes were also based on earliness and had a larger effect in the drier Sudanian and Sahelo-Sudanian regions than the maize programs. With the droughts of the early '80s, farmers often lost their cowpeas entirely, including seeds for the next year. This made them more receptive to trying out the new experiment-station cultivars, especially new varieties with earliness for drought escape. New cowpea diffusion also occurred at a rapid rate in the higher-rainfall Guinea savanna.

A number of new sorghum cultivars have been introduced in West, Central, and East Africa, including E 35-1, Framida, S-35, Serena, Seredo, Gambella, Hageen Dura-1, and SRN-39. Nevertheless, given the specific mandate of ICRISAT to work in the semi-arid regions on sorghum and millet and the large amount of financial and human resources commitment there, why was there much less success in the sorghum and millet programs than in the maize and cowpea programs? Some of the factors associated with price risk and the generally harsh production environment for sorghum and millet have already been discussed.

In the main sorghum regional program for West Africa in Burkina Faso, sorghum breeding attempted over almost 11 years to introduce Indian germplasm. With the exception of S-35 in the

Sudanian zones of Cameroon and Chad, this attempt to introduce Indian material was not successful. The Indian sorghum and millet experience was very successful there; however, the production environments in the Sudanian and Sahelo-Sudanian zones of West Africa are apparently harsher. The very high temperatures at planting were a major constraint to the introduction of the Indian material (Matlon, 1987, 1990). The inability of the central (Hyderabad) and regional ICRISAT research units to respond to the repeated information on the failure of the breeding strategy was a major administrative breakdown. The advantage of IITA of being in the region and utilizing excellent African scientists for coordinators may also be a factor in contributing to its greater successes in maize and cowpeas.

Earliness and some resistances in new cultivars, associated with higher chemical use in the Guinea savanna zone were all substantial achievements. These were principally successes of the IARCs and the NARS with some contribution in orientation and diffusion from SAFGRAD; however, some of the credit for the gains in confidence and the empowerment of the NARS has to go to SAFGRAD. This was an important achievement for the '80s. In the '90s more of the research system will be client rather than donor driven.

The next round of new technologies will require varietal and agronomic improvements for sorghum and millet in the Sudanian and Sahelo-Sudanian zones, respectively. In the Sudanian zone water-retention techniques will need to be combined with increased use of chemical fertilizer (Sanders et al., 1990). In the Sahelo-Sudanian zone, improvements in millet cultivars and increased fertilization will be necessary (Shapiro et al., 1993). This will be difficult on these sandy-dune soils. For the lower-rainfall regions of the Sahelo-Sudanian zone, it will probably be more efficient to increase cereal yields in other climatic zones with higher crop production potential and encourage a shift in land use here to agro-forestry with grazing. This will be an especially difficult human adjustment problem in countries with high population densities in the Sahelo-Sudanian zone, such as Niger.

For the Guinean region new production systems including a legume are necessary to reverse the declining organic matter in the soil (Sanders, 1989). Chemical fertilizer use on cotton and maize is already at reasonably high levels and is increasing in these Guinean production systems even with the elimination of fertilizer subsidies. Also in these systems, improving the quality of forages and better integration of livestock and crops are important and difficult research areas. Moreover, continuing maintenance research is necessary to sustain the higher yields obtained since agriculture is a dynamic system and the sources of biotic and abiotic pressures are continuously evolving.

## APPENDIX A

### SAFGRAD Contribution

At the beginning of SAFGRAD in 1978, most of the germplasm and the technological concepts came from the IARCS. For example, for earliness in maize the gene pool came from CIMMYT, IITA, and local sources. With USAID resources, SAFGRAD-I funded the continued breeding activities leading to new early material, which was introduced and then imitated by other countries. Other cases of direct SAFGRAD support of research will be identified.

Perhaps the most important contribution of SAFGRAD has been its facilitation of training, scientific collaboration, and confidence-building to the NARS. Note that the IARCs and other institutions actually did the training but SAFGRAD helped the NARS define their training requirements and get access to the training.

In the late '70s the NARS received germplasm from the IARCs and an important proportion of the research funds came from the donors. Much of the NARS research was donor driven. Also in the '80s many countries received an important share of the funding for research from special donor-funded programs for cereals research and/or extension. By the second half of the '80s and in the early '90s the regional variety trials contained an increasing proportion of NARS materials. The IARCs' contribution, at least for the larger NARS, is shifting to concepts rather than providing material. In the '90s the NARS are increasingly making their own decisions on research priorities and research strategies with the technical backstopping of the networks, the IARCs, and a new player in the game, the CRSPs. The CRSPs are U.S. government-supported, multi-university commodity or resource programs to increase productivity in developing countries by building up the ties between scientists in developed and developing countries. As the NARS establish themselves with scientifically qualified personnel and functional institutions, they increasingly will expect to set their own research priorities. This has been a major evolution for the larger NARS, and SAFGRAD has played a major role in this empowerment of the NARS. How to achieve economies of scale, adequate training, and technical efficiency in the smaller NARS is a major technical question now for these NARS and for the donors.

Another major concern is that the donors are no longer supporting these national or regional cereals programs. Donors' interests change; there are substantial financial demands of assistance from the formerly Communist countries; and the economic problems in developed countries in the '90s, such as Canada, are leading to reductions of assistance to Sub-Saharan Africa. Increasingly, national governments in Sub-Saharan Africa will have to pay for much larger shares of their research and extension costs. Research is a high-cost investment but with very high payoffs. Some of these high returns have been documented here and others cited. However, this information on the very high social returns to research will have to reach national policymakers so that research is able to compete for its share of the national budgets in developing countries.

## APPENDIX B

### The Returns to All Maize Research and to SAFGRAD Supported Maize Research in Ghana

Maize is Ghana's most important cereal crop and it was grown on 610,000 ha in 1991. The analysis of the national maize program here begins with the return of a breeder in 1968 from CIMMYT. There had been activity and the release of some new material before that but the takeoff of the program as reflected in the steadily increasing proportion of new cultivars introduced took place in the late '70s and '80s. In 1979 20% of the maize area was in improved cultivars. In 1980 the program had expanded to three breeders, an entomologist, an agronomist, and half the time of a pathologist. CIMMYT estimated that 43% of the area was in improved maize cultivars in 1988. The estimate of the former coordinator of this Ghanaian program was that 55% of the maize area in 1992 was in improved cultivars. So this is an impressive success story. The procedure here will be to first make some estimates of the costs and benefits of the overall national maize program. Then those benefits to the national program of the technology specifically associated with SAFGRAD will be separately estimated.

The evolution of the national maize team is given below:

#### Personnel in the Maize team:

1968 - One breeder, 1/2 agronomist, 10%; pathologist, 5% entomologist.

1975 - One breeder, two assistant breeders, 1 assistant agronomist, rest of above.

1979 - One breeder, two assistant breeders, 1 agronomist, 1 economist, rest of above.

1986 - 3 breeders, 2 on-station agronomists, 3 half-time on-farm agronomists, rest of above.

1991 - To rest of team above add 1 biochemist and one rural sociologist.

The success of the maize program is illustrated by the release of new material. The area in new cultivars increased from 5% in 1968 to 55% in 1991. The introduction of the new early material associated with SAFGRAD is also reflected in Table A-1.

**Table A-1. Introduction of all Maize Cultivars  
and of the SAFGRAD-Supported Early Material in  
Ghana, 1968-1991.**

<b>Year</b>	<b>All Improved Material</b>	<b>SAFGRAD Material</b>
1968	5%	
1969	6%	
1970	7%	
1971	8%	
1972	9%	
1973	10%	
1974	11%	
1975	15%	
1976	16%	
1977	17%	
1978	18%	
1979	20%	
1980	22%	
1981	25%	
1982	25%	
1983	25%	
1984	30%	
1985	35%	
1986	40%	2.0%
1987	42%	3.0%
1988	45%	3.5%
1989	47%	3.5%
1990	50%	4.0%
1991	55%	4.0%

The IITA-SAFGRAD program of the early '80s looked for earliness so that maize production could be expanded in the semi-arid zone, especially in the Guinean savanna and more recently for extra earliness into the drier Sudanian zone. This was a new area of research focus not pursued by either IITA or CIMMYT. CIMMYT has carried on a research program to identify plant characteristics associated with drought tolerance. This emphasis by SAFGRAD on plant characteristics to enable maize to attain higher productivity in semi-arid regions was consistent with the mandate of SAFGRAD. Successfully-released early, national varieties have been SAFITA-2 and Kawanzie. More recently the streak-resistant variety, Dorke SR, was released. All three new maize cultivars mature in 90 to 95 days. Material from the Ghanaian program exchanged in regional trials has also been released as new cultivars in Mali (Golden Crystal) and Cameroon (Mexican 17 Early). So successes with both a new direction of breeding and with the international exchange of material of SAFGRAD are reflected in this successful diffusion.

The diffusion of the new cultivars now needs to be converted into shifts of the supply curve in order to estimate the economic benefits of the introduction of the new cultivars.

#### **ADDITIONAL INPUT COSTS OF THE NEW MAIZE CULTIVARS:**

The improved cultivars are associated with higher input costs for purchasing seed and chemical fertilizer. One of the main advantages to the new maize cultivars is to raise the returns to and encourage the introduction of increased chemical fertilizer. Moreover, there are additional expenditures for the improved seeds. To simplify these initial calculations, the 1991 prices in cedes were utilized for fertilizer, seeds, and for the exchange rate from cedes to dollars. Estimates of these prices and of the fertilization and seeding rates were obtained from the national maize program of Ghana. Increased expenditures for seeds and fertilizer purchases are first estimated and then deducted from gross benefits to give net social benefits.

Changes in consumer and producer surplus are calculated following the Akino-Hayami technique. Border prices were used for calculating the value of production (international prices and transportation costs from Salinger and Stryker, 1991). Then the costs of the additional seed purchases and fertilizers were deducted to give the net social benefits resulting to Ghana from the technological change in the maize program.

So the net social benefits for the entire maize program ranged from \$4.8 to \$154 million per year over the period 1982-1991. The benefits to the SAFGRAD-associated early cultivars were much smaller as they were only introduced on a small area, 2 to 4% of the Ghanaian maize area from 1986-1991. Moreover, their yield effect was estimated to be only 20%. The principal benefit

of early cultivars is risk reduction through drought escape rather than substantial yield potential in normal and good rainfall years. The net social benefits from the SAFGRAD-associated, early cultivars ranged from \$400,000 to \$1.4 million per year. SAFGRAD provided many other more intangible benefits to the Ghanaian maize program. Moreover, these estimated benefits to earliness came at no additional costs to the program outside of the usual research and extension costs that were undertaken anyway.

### EXTENSION COSTS:

The former head of the national maize program travelled to Ghana and obtained estimates of the total extension costs and the contributions for extension from the principal donors. The estimates were obtained in cedes and converted to dollars with the official exchange rates for 1991 and 1992.

**Table A-2. Dollar Expenditures for Maize Extension in Ghana, 1991 and 1992.**

		FUNDING SOURCE (U.S.\$)		
Year	Govt. Ghana	Global 2000	World Bank	USAID
1991	1,900,457			
1992	1,443,662	410,485	65,904	298,946

For Global 2000 it was estimated that 60% of its expenditures were for maize. For the other three funders 40% was used for maize's share. The donors became interested in Ghanaian extension during the structural adjustment program of the mid-'80s. To approximate maize extension costs, it was assumed that these expenditures stayed at 1991-92 levels from 1986-1991. For the decade prior to 1986 the government of Ghana was assumed to have spent 85% of its 1991 budget. For 1973-1976, it assumed it had spent 65% of this budget. Obviously, these numbers could be improved with some systematic tracking of these expenditures. Extension costs are an important component of the costs of getting new material from the research station onto farmers' fields. Moreover, extension often is a substantial cost item, much larger than research costs since salaries and support of well-trained African scientists tend to be very low. Most studies of the returns to research have little to say about the extension costs.

## APPENDIX C

## Estimating the Returns to Cowpea Research in Burkina Faso and Mali

Increasing the yields of grain legumes is more difficult than that of cereals. The yield gains for sorghum and maize have been much more rapid and the absolute yield increases greater than for soybeans in the U.S. and other developed countries. Grain legumes in the tropics have a large number of insect pests and are a secondary crop generally grown in association with cereals and with minimal purchased inputs. Since insect problems can be devastating both in the field and in storage, farmers frequently lose their seed and then have to purchase seed from other farmers or from the public sector. This turnover of seed is often an advantage for the initial diffusion of new cultivars. However, the widespread selling of a new cowpea cultivar, as in 1985 after the drought of 1984, does not yet imply successful diffusion. It reflects the loss of the crop in 1984.

On the experiment station monoculture cowpea yields can range between 1 to 2 t/ha. This would include adequate fertilization, principally with phosphorus, frequent spraying to control insects, and good nitrogen fixation. In the farmers' fields, maintaining cowpea yields even at the low present levels is an achievement. Here, measuring the benefits to maintenance research will be attempted. Without the introduction of the new cowpea cultivars, drought, insects, and *Striga* would have even further reduced farmers' yields in the two Sahelian countries of Burkina Faso and Mali.

The breeders' objectives in these two countries were earliness for drought escape; resistances or tolerances to disease, insects, and *Striga*; favorable taste characteristics; and higher yields. If success is evaluated by diffusion onto farmers' fields, the cowpea program in these two countries was very successful. Tables A-3, A-4, and A-5 summarize the diffusion information for the three principal climatic zones in the Sahel.

**Table A-3. Diffusion of New Cowpea Cultivars in the  
Guinean Zones of Burkina Faso and Mali.**

REGIONS				
	SOUTHERN BURKINA			SOUTHERN MALI
Year	KN-1	TVX 32-36	KVX 396	KN-1
1982	Release			Release
1983				
1984		Release		
1985				
1986				
1987				80%
1988				
1989	80%	20%	Release	
1990				
1991				
1992	80%	10%	10%	

Source: Dr. Muleba, Cowpea Breeder, IITA-SAFGRAD.

Table A-4. Diffusion of New Cowpea Cultivars in the Sudanian Zones of Burkina Faso and Mali.

Year	CENTRAL BURKINA REGION					CENTRAL MALI REGION			
	KN-1	TVX 32-36	KVX 61-1	KVX 30	KVX 396	KN-1	TN 88	KVX 30	KVX 61
1981	Release					Release	Release		
1982									
1983	60%								
1984	30%	Release							
1985		10%							
1986		40%							
1987	20%	40%				60%	20%		
1988	0	20%							
1989		10%	Release	Release	Release			Release	Release
1990		10%	10%	10%	10%				
1991			15%		15%			15%	15%
1992			20%		20%				

Source: Dr. Muleba, Cowpea Breeder, IITA-SAFGRAD.

Table A-5. Diffusion of New Cowpea Cultivars in the Sahelo-Sudanian Zones of Burkina Faso and Mali.

Year	NORTH CENTRAL BURKINA REGION					NORTH CENTRAL MALI REGION		
	Suvita 2	KVX 61	KVX 30	KVX 396	IAR 71	Suvita 2	KVX 61	KVX 30
1984	Release							
1985								
1986						Release		
1987								
1988								
1989	100%	Release	Release	Release		80%		
1990	70%	10%	10%	10%		100%	Release	Release
1991	60%	15%	10%	15%	Release	90%	5%	5%
1992	55%	15%	10%	15%	5%	5%	80%	10%

Source: Dr. Muleba, Cowpea Breeder, IITA-SAFGRAD.

## CALCULATION OF THE BENEFITS TO COWPEA RESEARCH

The above data provided the base for the extent of diffusion. The proportion of the production in each zone was estimated to be: Guinean zone-40%; Sudanian zone-45%; and Sahelo-Sudanian zone-15%. Yields on farmers' fields were estimated to be from 200 to 400 kg./ha. in association with minimal purchased input use.

In the absence of the new cultivars with the continuing problems of drought, Striga, insects and diseases of the '80s and '90s farm yields would have fallen by at least 50% and perhaps by 100% since the new cultivars did largely replace the traditional ones. To be conservative the benefits to research were calculated for 25% and 50% yield declines.

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