PARTNERSHIP IN ON-FARM VERIFICATION TRIALS FOR INCREASED FOOD GRAIN PRODUCTION IN WEST AND CENTRAL AFRICA

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ACKNOWLEDGEMENTS

The project focus has been on narrowing the 'yield gap' of the performance of crop production technologies between on-research station and that on farmers' fields. The Food Grain Production Technology Verification Project was implemented through the partnership and genuine cooperation of the national research and extension-development institutions (indicated in Annex 9) and through the active and enthusiastic participation of several farmers as beneficiaries from the project activities. In the total effort of enhancing the adoption of food grain production technologies, OAU/STRC-SAFGRAD wishes to express its appreciation to the African Development Bank for its financial assistance.

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Dr. J.M. Menyonga
International Coordinator

EXECUTIVE SUMMARY

This report highlights the results of the "Food Grain Production Technology Verification Project" activities that were implemented in eight countries through the financial assistance of the African Development Bank.The project purpose has been to narrow the "yield gap" of the performance of crop production technologies between on-research station and on-farmers' fields; to continuously deliver technologies to national extension systems; and to eventually provide several technological options to resource-poor farmers.

In Burkina Faso, more than 600 farmers were involved in conducting on-farm verification trials in 12 regional agropastoral extension development zones. Three new cowpea cultivars (KVx396-4-4, KVx61-1, and KVx30-309-66) and improved agronomic practices adapted to Sahel, Sudan and Northern Guinea Savanna zones were identified. The adoption of and the preference for these cowpea cultivars have been due to their attributes of good seed quality, high yield, earliness and for the production of fodder. Minimum levels of insecticide spray schedule for the major ecological zones in Burkina Faso were also determined. For example, in the high insect pressure zone (including Central and Eastern zones), there was a yield advantage (over unsprayed fields) of 68 to 133% for single and two insecticide sprays, respectively. In the low insect pressure zone (including Southern and Sahelian zones), the yield advantage (over usprayed fields) was 73 and 119% for single and two insecticide sprays, respectively.

In Cameroon, improved agronomic packages (improved varieties, fertilizer, plant population, etc.) were developed for early and extra-early maize cultivars. Through the project assistance, two suitable early maturing maize cultivars namely, DMR-ESRY and Pool-16DR-SR were released for the low-land savanna zone, in Northern Cameroon. These varieties are appreciated by farmers due to their earliness and for use as "green maize" (within 65 days from planting) during the hunger period, before sorghum and millet harvest. For market gardeners, the sale of green maize has also become a source of income.

Seeds of the above varieties were increased and distributed to more than 1500 farmers. The yield advantage of the improved agronomic packages over tradditional farming practice was about 40% more grain yield (1.3 tons/ha), an additional income of 65 000 FCFA/ha.

In Northern Ghana, various cropping systems were evaluated. For example, in Bimbilla district, involving ten villages and 35 farmers, the grain yield of maize and groundnut under alley cropping system (including cereal/pigeonpea), has increased yield by 188 and 54%, respectively than traditional farmers' practices. Cereal/legume rotation trials were conducted in 14 villages in Northern Ghana. Compared to farmers' practice, when maize, sorghum and groundnut were cultivated in rotation, yield increased by 72, 31 and 61%, respectively.

In Mali, the varieties EV-8422-SR (115 days to maturity), DMR-ESR-Y (80-90 days), and TZEF-Y (70 days) were found to be most promising. A total of 37 farms were involved in the study. In the medium maturity class, the variety EV-8422-SR produced higher yield (4.20 t/ha) and showed good resistance to maize streak virus than the improved checks, Tiémantié (3.66 t/ha) and Tuxpeno (4.10 t/ha). On-farm verification trial yields represented as much as 91%, 88% and 86% of the yields obtained on research station for these varieties, thus narrowing the "yield gap" between on-research station and on-farmers' fields.

In Niger, the emphasis of the study has been to improve the productivity of the millet/sorghum-based system. Traditionally, farmers rarely apply commercial fertilizer or

organic manure. The trials consisted of mixed planting of traditional and improved sorghum and millet cultivars with and without fertilizer application.
The results of these verification trials indicate:

- Positive yield response of sorghum and millet to phosphate and nitrogen fertilization. Yield of these crops on farmers' fields (both with local and improved cultivars) either doubled or tripled.

- Intercropping of millet and sorghum or legume could also improve the productivity per unit area by 50 to 75 percent.

In Nigeria, the major cropping practices are sorghum/millet/cowpea or maize/cowpea mixtures. The verification trials comprised improved cowpea variety SAMPEA-7, sorghum variety KSV8, and millet variety SE13 in Yandoto area. They gave yields of 2.5, 2.2, 1.3 tons/ha for sorghum, millet and cowpea, respectively. These yields were 6-8 times higher than those recorded in Zogsarawa area, leading to greater economic returns in Yandoto. However, the yield advantage of improved varieties over local cultivars was much higher in Zogarawa region than in Yandoto area. A total of 41 farmers participated in the operation in Yandoto (high rainfall, animal traction) and Zogarawa (low rainfall, manual cultivation) areas.

Nitrogen application of 75 kg/ha increased maize yield (TZBSRW) from 545 to 3710 kg/ha. Further increase of nitrogen more or less depressed the yield of the crop. Maize also responded positively to phosphorus fertilization up to 40 kg/h $P_2 0_5$ where yield improved from 2747 (without P) to 3160 kg/ha (with P application). Increasing potassium (K) level up to 60 kg/ha K20 impact decreased yield of maize from 3155 to 2890 kg/ha.

In Senegal, two improved millet cultivars namely, Souna-3, and IBV8004 were evaluated in Central South and North regions respectively. The variety Souna-3 was compared to the farmer's local variety under improved agronomic practices. With the addition of 2 t/ha of farm manure to half dose of the recommended fertilizer rate, IBV8004, gave a yield of 988 kg/ha, 14% more than the full recommended rate of commercial fertilizer. The yield increase over traditional practice has been by more than 160%. With the same level of fertilization, the yield of Souna-3 was 159% more than traditional farming practice. The application of 2 t/ha farm manure alone produced 618 kg/ha for improved millet cultivars, IBV8004 and 889 kg/ha for Souna-3, with 67% and 32% increase, respectively, over the traditional farming practice. These results suggest that low organic matter content has been more limiting to millet production in Northern Senegal than in the South.

Millet-based cropping systems were evaluated in several regions. In Kaolack region, both yield and economic analysis revealed benefits from sole cropping of Souna-3, whereas intercropping with cowpea (1:1 ratio) gave better results in Fatick region. In Diourbel and Thies regions, intercropping millet variety IBV8004 with cowpea variety Ndiambour (1:2 ratio) was more profitable than sole cropping. The reverse was observed with the improved millet variety IBV8004/58-74 and cowpea culitvar intercropping.

Several new cowpea varieties were evaluated under farmer management in 6 villages in the Northern and Southern ecologies of Central Senegal where cowpea is widely grown. Results indicated that the best adapted introductions were varieties IS86-275 (Mouride) and B89-504 (Melakh) with average yields of 552 kg/ha and 673 kg/ha, respectively, which represent 8% and 32% yield advantage compared to the 511 kg/ha of the local check variety Ndiambour.

In Togo, the project is sited in the Kara region, with a population of 425,000 people. Sorghum, millet, maize, groundnut, cowpea, and yam are important staple food crops. Two improved sorghum varieties, Framida and Malisor 84-1, were grown in sole culture or in association with cowpea variety KVx396-4-4 with fertilizer application of 100 kg/ha NPK (15:15:15) and 50 kgh/ha urea. Under monoculture, sorghum produced 954 kg/ha, which was only 12% more than its performance when cultivated in association with cowpea. In contrast, sole cultivation of cowpea increased its yield three fold over mixed-cropping. Economic analysis of the mixed cropping systems showed a revenue of 89,131 FCFA/ha, about 5% less profitable than cowpea sole cultivation. Based on the results of the on-farm verification trials, mixed cropping with sorghum and cowpea varieties mentioned above is recommended to ensure both food security and generation of income at house-hold level.

Since 1990, three agronomic annual planning and review workshops were organized, where researchers from participating countries, regional and international research and development organizations exchanged technical information and experiences related to on-farm research and technology adoption. Furthermore, consultants were fielded (each year) to assess the implementation of project activities in the eight participating countries.

List of National Researchers who participated in the Implementation of Project Activities.

Project Director:	Taye Bezuneh Director of Research OAU/STRC-SAFGRAD.
NARS Researchers:	
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K.A. Elemo and O.O. Olufajo	Cropping Systems Agronomist and Grain Legume Agronomist, respectively, Institute for Agricultural Research, Ahmadu Bello University, Nigeria.
N'tji Coulibaly	Agronomist, Maize Improvement Programme, IER, Mali.
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Jeremy T. Ouedraogo Clémentine Dabire Issa Drabo	Grain Legume Breeder and Entomologist, respectively. Institut d'Etudes et de Recherches Agricoles, Ouagadougou, Burkina Faso.
Cissé Ndiaga Samba Thiaw	Grain Legume Breeder and Agronomist, respectively. Centre National de Recherche Agricole (CNRA), Bambey ; ISRA, Senegal.
Payaro P. Toky	Ingénieur Agronome, SAFGRAD/DRA Kara, Togo.
Saliou Diangar	Agronome, Centre National de Recherche Agricole (CNRA) Bambey, ISRA, Senegal.

Consultants (4-6 weeks field level assessment of project implementation).

A. M. Emechebe	Plant Pathologist, Institute for Agricultural Research, Ahmadu Bello University, Nigeria, 1990.
Michel P. Sedogo	Soil Scientist and Director General, CNRST, Burkina Faso, 1991.
K.A. Marfo	Agricultural Economist, Crops Research Institute, Kumasi, Ghana, 1992.

INTRODUCTION

This report highlights the results of the "Food Grain Production Technology Verification Project" whose activities were implemented in eight countries through the financial assistance of the African Development Bank. The project has enhanced on-farm verification trials involving farmers, and extension development agents through " research-extension-interphase" activities.

The main objectives of this project are:

i) To narrow the "yield gap" of the performance of technologies between on-station and on-farmers' field, which has been one of the missing links prior to enhancing the adoption of improved crop production innovations. The project is intended to speed up the process of transforming research results into extension recommendation and production.

ii) To promote and forge linkages between on-station and on-farm technology verification trials so that broad technological options are delivered to the farmer. Consequently, the extension agents would have easy access not only to technology, but also would acquire updated information and technical knowledge about the particular innovation being promoted for adoption. Concurrently, researchers, through such a "research-extension-interphase" activity could receive direct feedback information on the performance of a particular technology (at early stage).

iii) To facilitate the delivery of technological options that could minimize risks of crop failures due to environmental and socio-economic constraints.

To partially attain the above objectives, on-farm verification trials were initiated in eight participant countries as summarized in Table 1. In the eight countries, about 28 technological options were evaluated in nearly 100 villages. The number of farmers who participated in the management of on-farm verification trials has increased from 400 to nearly 1200 during the three-year period. The number of farmers with access to demonstration trials varied substantially from one country to another. For example, in Burkina Faso, samples of seed of improved cowpea cultivars were provided to 32,000 farmers; in Cameroon, seed of improved early and extra-early maize cultivars were provided to more than 15,000 farmers.

Table 1. Project sites, farmers' participation and number of technological options evaluated in the eight participating countries

Country	Project Sites (villages)	Number of farmers managing trials			Farmers with access to trials	Technological options verified
		1990	1991	1992		
Burkina Faso	12	197	509	112	32,000	3
Cameroon	15	20	25	25	50,000	4
Ghana	32	70	70	650+	10,000	4
Mali	25	NA	19	25	40,000	2
Niger	2	10	15	NA	2,000	5
Nigeria	9	NA	30	73	20,000	4
Senegal	30	30	50	80	50,000	4
Togo	5	100	150	215	6,000	2
TOTAL	130	427	868	1180	210,000	28

Source - (Ref. 1, 6 and 10)

NA - Not Available

I. HIGHLIGHTS OF ON-FARM AGRONOMIC VERIFICATION TRIALS.

1.0. BURKINA FASO.

VERIFICATION OF COWPEA PRODUCTION TECHNOLOGIES.

Cowpea is an important grain legume cultivated largely in association with sorghum and millet in the Central Highlands of the Mossi Plateau. Being an important source of protein, it is a common ingredient in the diet of most of the 9.0 million inhabitants of Burkina Faso. Due to lack of high yielding cowpea cultivars resistant to insect pests, diseases, etc, the average yield of cowpea by farmers has been rather low (250-300 kg/ha).

The Central Mossi Plateau is the most densely populated part of Burkina Faso. In some localities, the density nearly doubles the carrying capacity (40 to 60 inhabitants/km^2). As a result, there is migration from the Plateau to the Southern part of the country and to neighbouring countries. The region has few permanent water sources.

On the other hand, it has a relatively good road network system which links the capital, Ouagadougou, the major consumption centre. The rationale of the project has been that the need for agricultural instensification would be more relevant in the regions of highest population density since the traditional agricultural system can no longer meet food and energy requirements.

Cowpea is cultivated as an important grain legume in the three major ecological zones namely, the Sahel, Sudan savanna and the Northern Guinea savanna. Typically, the Sahel zone has limited surface water resources. Rainfall is monomodal in pattern, low in amount and poor in distribution. The total precipitation varies from under 300 mm/year in the northern most parts to about 600 mm/year in the south. Relatively low temperatures (10-15°C) characterize the period from November to February, whilst April and May record average day temperatures of 40°C and above. The length of the growing season varies from 2 to 4 months (June to October), with the dry season lasting from October/November to May/June.

The Sudanian zone of Burkina Faso is characterized by three distinct seasons : warm and dry from November to March, hot and dry during March to May and hot and moist from June to October. The mean annual rainfall ranges from 600 mm in the North, bordering the Sahelian zone, to 1000 mm in the South, near the North Guinean zone with 4-5 months of rain. The rainy season starts between mid-May to mid-June and stops rather abruptly around early October. Temperatures are high, especially just before and right after the rainy season, with day-time values reaching up to 40°C. The hot dry winds from the Sahara further aggravate the drought conditions. Potential evapo-transpiration is high throughout the year, with a mean value of 1900 mm. Although rainfall exceeds evapotranspiration during some months, periods of moisture stress are frequent and unpredictable. The drought periods are pronounced during critical crop growth stages: seedling, flowering and grain formation.

The Northern Guinea savanna has relatively more dependable rainfall of 850-1100 mm/year, spread over a 4 to 6 month period. Soils are largely alfisols and types similar to those of the Sudanian zone. Maize is the predominant cereal, with sorghum cultivated largely in the transitional Sudano-Guinean zone where the rainfall range is between 700-900 mm. Cowpeas and groundnuts are the important pulses, usually intercropped within cereals. Cotton is an important industrial crop in this zone.

i) **Project Objectives.**

From institutional development perspectives, the purpose of this project support has been to enhance the national capacity for the evaluation and adoption of cowpea production technologies. This involved, research and extension interphase activities between the National Agricultural Research Institute (INERA) and the National Agropastoral Extension and Development Centre (CRPA). The main objectives of the project are:

(a) To identify suitable cowpea cultivars adapted to the three main ecological zones (Sahel, Sudan and Guinea savannas).

(b) To determine and to minimize insecticide spray requirements in controlling insect pests in different ecological sites.

ii) **New Cowpea Cultivars Adapted for Different Agro-climatic Zones were Identified.**

Four new cowpea cultivars were evaluated in association with millet, sorghum and in monoculture in the 12 major districts involving 197, 509 and 188 farmers in 1990, 1991 and 1992, respectively.

In general, the new cowpea cultivars gave higher yields with the exception of local cultivar, Gorom which gave the highest yield (1792 kg/ha) in 1990 in the Sahelian Province, where several on-farm trials were carried out. In the Sahel region, the highest yield was obtained with TVx3236 and mix-cropped with millet, KVx396-4 outyielded by more than 63 and 56% over local cowpea cultivars, respectively (Table 2). In the northern part of the Sahelian zone, the varieties KN-1, intercropped with millet gave much lower yield (256 kg/ha). The same yield trend was also observed with Gorom.

In the Sudanian zone (which includes Centre-Ouest, Centre Sud, Est and Mouhoun Provinces), KVx396-4-4 intercropped with sorghum gave the highest yield, about 57% over the local check, whereas the combined yield (cereal/cowpea) was highest when KVx61-1 was intercropped with sorghum (1300 kg/ha). In the West-Central Province (rainfall 800 mm), the yields of KVx396-4-4, TVx3236 and KN-1 were not significantly different under sole cowpea cultivar. The two improved varieties that outyielded local check (in the Sudan zone) are KVx396-4-4 and TVx3236 both in crop association and pure culture (Table 3 and Fig. 1). Cowpea yield was suppressed from 60 to 200% when intercropped with millet in the Sahelian zone and 60 to 90% with sorghum in the Sudanian zone. This may be due to relatively more moisture stress in the Sahelian zone and the interaction of associated crops. Based on data observed from 1990 to 1992, KVx396-4-4 is the most adapted cowpea cultivar for crop association with both millet and sorghum in Sahelian and Sudanian zones (Tables 2 and 3).

In the Sahelian and Sudanian zones, the yield increase of the cowpea variety KVx61-1 was 38 and 47%, more than local cowpea cultivars, respectively. In the Northern Guinea savanna zone, the three improved cowpea cultivars outyielded the local check (500 kg/ha), but there was no significant yield difference among these cowpea cultivars (Table 4).

Table 2. Average yield of some cowpea cultivars (kg/ha) grown in association with millet and in pure culture in the Sahelian zone (1990-1992)*

Variety	Average yield-cowpea A	A Average yield- millet B	Average yield-cowpea/millet mixture C	Yield increase in % over local cultivar	Cowpea yield in monoculture
KVx396-4-4	386	370	756	+18%	1048
KVx30-304-66	396	303	699	+20	795
TVx3236	537	379	916	+63	1544+
KVx61-1	483	376	859	+47	792
KN-1	256	259	515	LYC	NA
Gorom	297	406	703	LYC	549
Local checks	328	377	705		940

* Average yield of three years (in kg/ha)

A = Yield of cowpea grown in association with millet

B = Yield of millet grown with cowpea

C = Cowpea and millet combined average yield of three years

LYC = Lower yield than local cultivar

NA = Data not available

\+ = Yield recorded for one season

Source: (Ref. 1,6 and 7).

Table 3. Average yield of some improved cowpea cultivars (kg/ha) grown in association with sorghum and in pure culture in the Sudanian zone (1990-1992)*

Variety	Average yield-cowpea A	Average yield- sorghum B	Cowpea/ sorghum combined yield C	Yield increase in % over local cultivar	Cowpea yield in monoculture (D)
KVx396-4	402	727	1129	57	771
KVx61-1	352	951	1303	37	683
TVx3236	381	669	1050	49	620
Local check	256	770	1026	-	494
KN-1	-	-	-	-	766
Gorom	-	-	-	-	737

* Average yield of three years (in kg/ha)
A = Yield of cowpea grown in association with sorghum
B = Yield of sorghum grown in association with cowpea
C = Combined yield of cowpea and sorghum
D = Cowpea grown in pure (sole) cultivation

Source: (Ref. 1,6 and 7).

iii) Minimum Level of Insecticide Spray to Control Cowpea Pests was Determined.

Recognizing that the production of cowpea is almost impossible without insect pest control and to concurrently sustain environmental safety, a minimum level of insecticide spray requirement was determined in the major cowpea production zones.

The production of improved cowpea varieties selected for high yields and good grain quality was severely restricted due to insect pests. Pending the reorientation of breeding programmes aimed at developing low insecticide demanding varieties, it was advisable to assess the actual insecticide treatment requirements in the various regions of the country.

The plant materials used for this study include three varieties: KN-1 with a potential of 1.5-2 t/ha, recommended for the Northern-Guinea Savana zone; KVx396-4-4 with a potential of 0.9-1.5/ha, adapted to the whole country (but more specially in the Sudan-Savana zone) and Local Gorom-Gorom, with a potential of 1.5 t/ha, proposed for the Sahel region.

The thrip population analysis led to a distinction between high infestation zones including Central and Eastern regions; and low to moderate pressure zones comprising the other regions of the country. The latter are classified into Southern, Sahel and Cotton Zones according to their climate and the prevailing agricultural practices.

The trial consisted of three insecticide treatments: (i) plots treated with insecticide once,about 30 days after planting, at budding, to control flower thrips; (ii) plots treated twice, 30 days after planting, against thrips and 15 days later against pod sucking bugs and (iii) untreated plots. Flower samples were collected from treated and untreated plots a few days after the first treatment to assess the levels of thrip infestation. The study involved all the agricultural extension development centres known as "Centre Régional de Promotion Agro-Pastorale" (CRPA) in the country, except the one in the Centre West.

Without insecticide treatment, yields ranged from 312 kg/ha in the high insect pres sure zone to 531 kg/ha in the low pressure zone. With the application of a single treatment at 30 to 35 days after planting, yields increased by 32% in the Sahel zone, 33% in the cotton zone, 68% in the Central zone and 73% in the Southern zone. A second treatment applied 10-15 days later gave an additional production varying from 24% to 51% over the yields obtained from the first treatment (Table 5 and Fig. 1).

The analysis of cumulated yield gains suggests that the gain associated with treatment against insects (45 to 50 days after planting) is substantial in most zones, but relatively low in the cotton zone. In contrast, treatment against thrips (30 to 35 days after planting) proves to be optional in the Southern and Sahel zones, but indispensable in the Central and Eastern zones of Burkina Faso.

Table 4. Average yield of some cowpea cultivars (kg/ha) evaluated in pure culture in the Northern Guinea Savanna zone (1990-1992).

Average	YEAR			Average yield*
	1990	1991	1992	
KVx396-4	653	619	792	688
KVx3236	664	613	790	689
KN-1	692	528	657	626
Local checks	-	-	-	500

* No significant yield difference among improved cowpea cultivars.

Source: (Ref. 1,6 and 7).

Table 5. Effects of insecticide spray on cowpea yield (kg/ha) in Burkina Faso.

Infestation zone	Untreated plot (TO)	Single treatment (T1)	Yield difference in kg. YD	Percentage yield increase (% YI)	Two treatments (T2)	Yield difference in kg. (YD)	Percentage yield increase (% YI)
Central and Eastern zone (high insect pressure)	312	524	212	68	725	413	133
Southern zone (moderate insect pressure)	382	626	244	73	840	458	119
Sahel zone (low insect pressure)	460	606	146	32	921	461	100
Cotton zone	531	707	176	33	880	349	66

TO : Check, no insecticide application
T1 : Single insecticide application 30-35 days after planting
T2 : Two applications, the second 45-50 days after planting
YD : Yield difference attributed to insecticide treatment
% YI : Percentage yield increase over the check.

Source : (Ref. 1, 6 and 7).

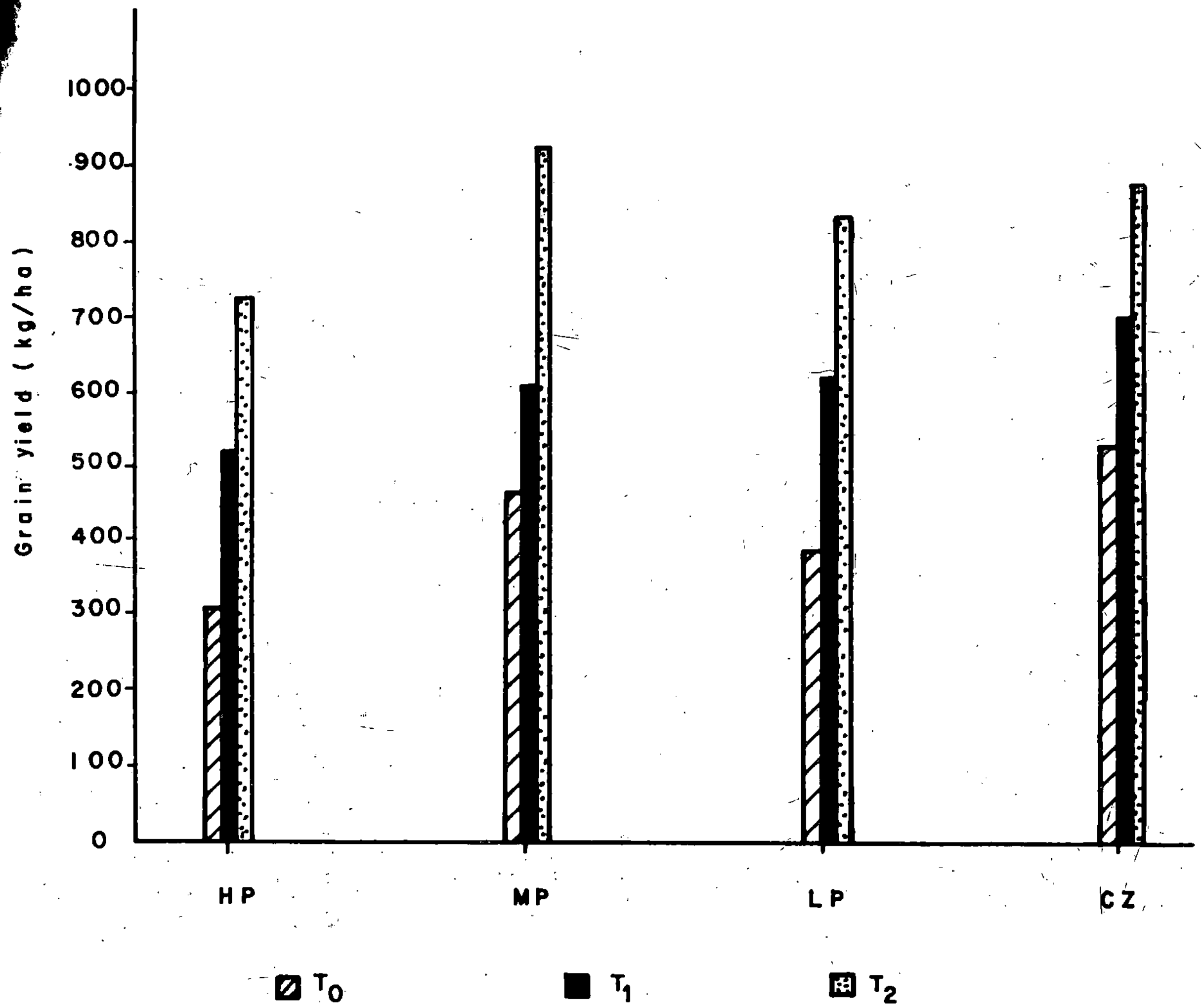

Fig. — The effect of insecticide treatment on the yield (kg/ha) of cowpea cultivated in different insect pressure ecological zones of Burkina Faso

Treatments (T)

T_0 — Without insecticide spray

T_1 — Single insecticide spray 30–35 days after planting

T_2 — Second insecticide spray after 50 days of planting

HP — High insect pressure zone

MP — Medium insect pressure zone

LP — Low insect pressure zone

CZ — Cotton cultivation zone

iv) Summary and Recommendations.

(a) In Burkina Faso, more than 600 farmers were involved in conducting the on-farm verification trials in 12 regional agropastoral extension development zones. The results of the on-farm trials over three years enabled farmers to identify three new cowpea cultivars namely, KVx396-4-4, KVx61-1, and KVx30-309-66.

(b) The adoption of and the preference for these cowpea cultivars have been due to their attributes of good seed quality, high yield, earliness and for the production of fodder. Recognizing that the production of cowpea is almost impossible without insect pest control, a minimum level of insecticide spray schedule for the major ecological zones in Burkina was determined. For example, in the high insect pressure zone (including Central and Eastern zones), there was yield advantage (over unsprayed fields) from 68 to 133% for single and two insecticide sprays, respectively. In the low insect pressure zone (including Southern and Sahelian zones), the yield advantage (over usprayed fields) was 73 and 119% for single and two insecticide sprays, respectively.

(c) The adoption of new cowpea cultivars by farmers is limited due to lack of seed supply. The project, however, has encouraged farmers to produce their own seed and by distributing improved seed to more than 30,000 farmers

(d) Research-extension-farmer interaction, through the project funding support, has enhanced national capacity for the verification and adoption of cowpea production technologies.

2.0. CAMEROON.

DEVELOPING IMPROVED AGRONOMIC TECHNOLOGICAL PACKAGES FOR PRODUCTION OF EARLY AND EXTRA EARLY MAIZE CULTIVARS IN THE LOW-DRY ECOLOGICAL ZONE.

The area under maize production in the semi-arid lowland savanna (North and Far North Provinces of Cameroon) has increased significantly during the last decade.

The annual rainfall of the region is quite variable (500-900 mm). Soil types at most village sites were classified as Alfisols, except at Makabaye where the soil type was described as Vertisol. The number of participating farmers and villages varied from year to year. In 1990, the on-farm verification trials were limited in the North Province and included the villages of Bokle, Djalingo, Mouda and Soucounda. The villages of Djoulgouf/Yoldeo, Djoulgouf/Awima, Gatouguel, Makabaye and Zouaye were added in 1991. The project also expanded its activities to Far North Province (relatively dry zone) and included the villages of Kougi, Lera and Lokoro in 1992.

(i) Early Maturing Maize Cultivars were Released for Farmers' Use.

Through this project support, on-farm verification trials were conducted to enhance the adoption of short-cycle maize cultivars in the semi-arid lowland savanna.

The main objective of the technology verification trials was to introduce extra-early (75-80 days) and early (80-90 days) maturing varieties of maize and improved agronomic practices to increase production in order to fill the food shortage gaps during certain months of the year. Improved agronomic packages for recommended maize cultivars include: (a) appropriate rate and timing of Nitrogen (N) fertilization; (b) determining the optimum plant population densities; and (c) developing appropriate weed management practices; and the use of by-products from local industries as partial substitutes for mineral fertilization.

Two composite open-pollinated early maturing varieties with wide agroclimatic adaptation, DMR-ESR-Y (yellow seeded) and Pool 16-DR-SR (white seeded), were developed through the SAFGRAD maize improvement and the Cameroon NARS collaborative research activities. These maize cultivars have short maturity cycles of 90 to 95 days with potential yields of 4 to 6 t/ha. When management and agroclimatic conditions are optimum, they are also resistant to maize streak virus, blight, and drought. Both DMR-ESR-Y (also known as CMS-8806) and Pool 16 DR-SR, released as CMS 9015 in Cameroon, are usually planted at the beginning of the rainy season, to alleviate food shortages during the hunger period, just two months before the harvest of traditional crops such as sorghum and millet.

An extra-early maturing maize cultivar, TZEF-Y (yellow seed) that could be harvested within 85 days was also identified. Improved agronomic packages to optimize its yield are being developed.

(ii) Appropriate Growth Stages of Maize for Nitrogen Fertilization were Determined.

The varietal response to four dates of nitrogen fertilization (N) was investigated. The treatments include a basal application of 100 kg/ha complete fertilizer of 15-20-15-6-1 (NPK + sulfur and boron), supplemented by 150 kgs of urea N/ha (applied one third at planting and two thirds topdress (at different times after emergence).

In 1990/91, the two early maturing maize cultivars (DMR-ESR-Y and Pool 16 DR-SR) were evaluated for their yield performance and related agronomic characteristics. Similar trials were conducted in the Far North Province (relatively drier zone) using the same varieties, DMR-ESR-Y (released as CMS-8806) and Pool 16 DR-SR (released as CMS-9015 in Cameroon).

As summarized in Table 6 , the results obtained accross various locations showed that, thehighest yields were obtained when urea N was topdressed 20-25 days after plant emergence of early or extra-early maize varieties. For example, the yield of the maize var. DMR-ESR-Y was 4.9, 4.4 and 4.0 tons/ha with N fertilization after 20, 25 and 30 days of plant emergence, respectively. The results suggest that topdressing with nitrogen may be given earlier for early or extra-early maize than the present recommendation for medium or late maturing maize in which N topdressing is given 30-35 days after emergence. On some relatively heavier soils with a relatively high humus content, delaying N topdressing up to 25-30 days after emergence may be advisable.

Although response to N topdress varied considerably in various regions, split application of N fertilizer proved superior to single application. On the average, the highest yield was obtained for varieties DMR-ESR-Y and Pool 16 DRSR with N topdressing 20 days after planting. The next best date of planting for N-application was 25 days after planting.

The results showed also in 1992 that high yield of early maize can be obtained in farmers' fields under farmer management. With the variety DRM-ESR-Y, maximum yield of 3.7 t/ha was obtained, when urea N was applied within 20 days after emergence (DAE). There was a significant response of early maize to timing of urea N topdress application, even though the magnitude of the response varied among villages. On the average, the best timing of urea N topdress application seem to be 20 DAE (Table 6). This treatment was associated with an increase in grain yield of 1.02 t/ha compared to ckeck (where all N from urea topdress was applied initially). As summarized in Table 7 , topdress of N within three weeks after plant emergence, increased the relative grain yield by almost 38%, generating extra monetary value due to extra yield of about 50,000 FCFA when the price of maize was 50FCFA/kg.

Table 6. Effect of different timings of N topdress application on grain yield (kg/ha) of early maize variety in the semi-arid lowland savanna of North Cameroon 1990/91.

	LOCATION		
Sites/Treatments	Bokle (Var DMR.ESR-Y)	Soucoundou (Var. Pool 16 DR SR)	Mouda (Var. Pool 16 DR SR)
T1 (20 DAE)	4 860	2 852	1 872
T2 (25 DAE)	4 391	2 669	1 465
T3 (30 DAE)	4 070	2 226	1 784
T4 (35 DAE)	3 922	2 396	1 105
T5 (N-top dress applied initially)	4 431	2 357	1 585

Note: DAE = Days after emergence. C.V. = 11.9% C.V. = 16.2% C.V. = 22.6%
Source: (Ref. 1,6 and 12).

Table 7. The effect of plant population densities on the yield (T/ha) of early and extra-early maize cultivars in the semi-arid lowland savanna of North Cameroon.

Plant Population	DMR-ESR-Y		Pool-16-DR-SR N.C.	TZEF-Y N.C.
	N.C.	F.N.C.		
T_1 - 62,500 plants/ha (80 x 20 cm, 1 plant per hill)	3.98	3.74(A)	2.97	1.62
T_2 - 62,500 plants/ha (80 x 40 cm, 2 plants per hill)	3.8	3.81(A)	2.90	1.40
T_3 - 83,000 plants/ha (80 x 30 cm, 2 plants per hill)	3.56	2.83(B)	NA	1.39
T_4 - 50,000 plants/ha (80 x 25 cm, 1 plant per hill)	3.60	3.11(B)	2.46	NA

Please note : Treatments followed by the same letter are not significant at 5% level.

N.C. North Province of Cameroon.
F.C. Far North Province of Cameroon.
N.A. Data Not Available.

Source: (Ref. 1, 6 and 12).

(iii) **Optimum Plant Population Densities in Maximizing Yield of Early Maturing Maize Cultivars on Farmers' Fields was Determined.**

Four plant population densities on the yield of early maturing maize cultivars were investigated. Planting was done with intra-row spacing of 20, 25, 30 and 40 cm with single inter-row spacing of 80 cm. The number of plants per hill was one for 20 and 25 cm spacing and two for the other treatments, which resulted in population densities from 50,000 to 62,500 plants/ha and 83,000 plants/ha. The best yield was obtained at a population density of 62,500 plants/ha (80 cm x 20 cm, one plant per hill practice). The varieties DMR-ESR-Y, Pool 16 DR-SR and TZEF-Y gave yields of 3.98, 2-97, and 1.62 t/ha, respectively. The next best planting option for farmers would be the 80 x 40 cm scheme with 2 plants/hill, which was not statistically different from 80 x 20 cm planting scheme with one plant/hill and also reduces planting time by half (Table 8).

The combined effect of plant population and Nitrogen fertilization on the yield of early maturing maize cultivars was also investigated. As depicted in Fig. 2, the three varieties i.e., DMR-ESR-Y, Pool 16 DR-SR and TZEF-Y respond significantly to Nitrogen fertilization, where the highest yields were attained when maize was planted 20 cm in the row and 80 cm between rows with N-fertilization rates of 90 to 135 kg/ha.

Furthermore, the yield performance of early maize cultivars under two levels of N-fertilization was determined. This experiment was conducted in farmers' fields at Kourgi, Lera, Lokoro and Djalingo villages in the Far North Province. As summarized in Table 9, the best yield of maize was obtained by a combination of improved varieties and N-fertilization, although the magnitude of grain yield increase varied from location to location.

Improved packages of technology (i.e., improved variety + higher level of N-fertilization + optimum population density) gave 40% grain yield increase over traditional practice (local cultivar + 100 kg/ha NPK + optimum plant population density). This yield increase of 1.3 t/ha corresponded to an added revenue of 59,000 FCFA/ha (Table 8). Because of the combined effect of N fertilization and improved variety, farmers' yields increased from 3.22 to 4.21 t/ha in Kourgi village; while the yield changes in Lera village were 3.9 to 4.6 t/ha, and that at Djalingo village were 3.0 to 3.92 t/ha.

iv) **Acceptance of Short-Cycle Maize Cultivars.**

An extension programme referred to as "Operation Maïs de Case" was initiated in 1990 by IRA/NCRE team. It has been conducted in the North and Far North provinces of Cameroon (and some locations of Chad). The maize varieties used were the SAFGRAD early varieties DMR-ESR-Y released as CMS8806 and Pool 16 DR-SR released as CMS 9015. These varieties have some special characteristics for this operation: earliness to be used as "green maize" during the hunger period (harvested green after 65-75 days) and ability to withstand various stress conditions due to their association with other crops and dry spells at the beginning of the cropping season. Furthermore, these cultivars have acceptable taste to the consumer. In the approach used in this operation, each farmer received a package of 300 g of seeds of either variety. Farmers planted them in the usual way in association with several vegetable crops usually near the compound. In 1992, packages of seed of DMR-ESR-Y and Pool 16 DR-SR were distributed to more than 1500 farmers supervised by SODECOTON, MINAGRI, Projet NEB, PNVFA, and Church groups. So far, the results have been quite interesting. The production of "maïs de case" shortens the hunger period by providing some source of food as well as some income (each ear is sold at about 25 francs cfa) at a critical period of the year. This operation will be continued.

Seed Multiplication.

Due to the high demand by the farmers as well as the agricultural agencies for these two SAFGRAD varieties in the Far North Province of Cameroon and Chad, seed multiplication of the two above mentioned SAFGRAD varieties was done in the areas of Djalingo and Bokle. Several farmers were also encouraged to produce seed for sale to other farmers during the following season (1992/93).

Table 8. Response of an early maize cultivar DMR-ESR-Y to different timings of urea nitrogen (N) application in the semi-arid lowland savanna in the Far North Province of Cameroon (1992).

Treatments (T)	Average yield t/ha	Yield-increase t/ha	RGY %	Monetary value of extra yield in FCFA++
T_1 - Urea-N-applied all at planting time.	2.68(B)*	-	100	-
T_2 - Urea-N-applied two thirds 20 days after emergence	3.70(A)	1.02	138	51,000
T_3 - Urea-N-applied two thirds 25 days after emergence	2.92(B)	0.24	108	12,000
T_4 - Urea-N-applied two thirds at 30 days after emergence	2.83(B)	0.15	105	7,500

* Treatments followed by the same letter are not significant at 5% level.
RGY% Relative Grain Yield
++ Price of 1 kg of maize = 50 FCFA.

Source: (Ref. 6 and 12).

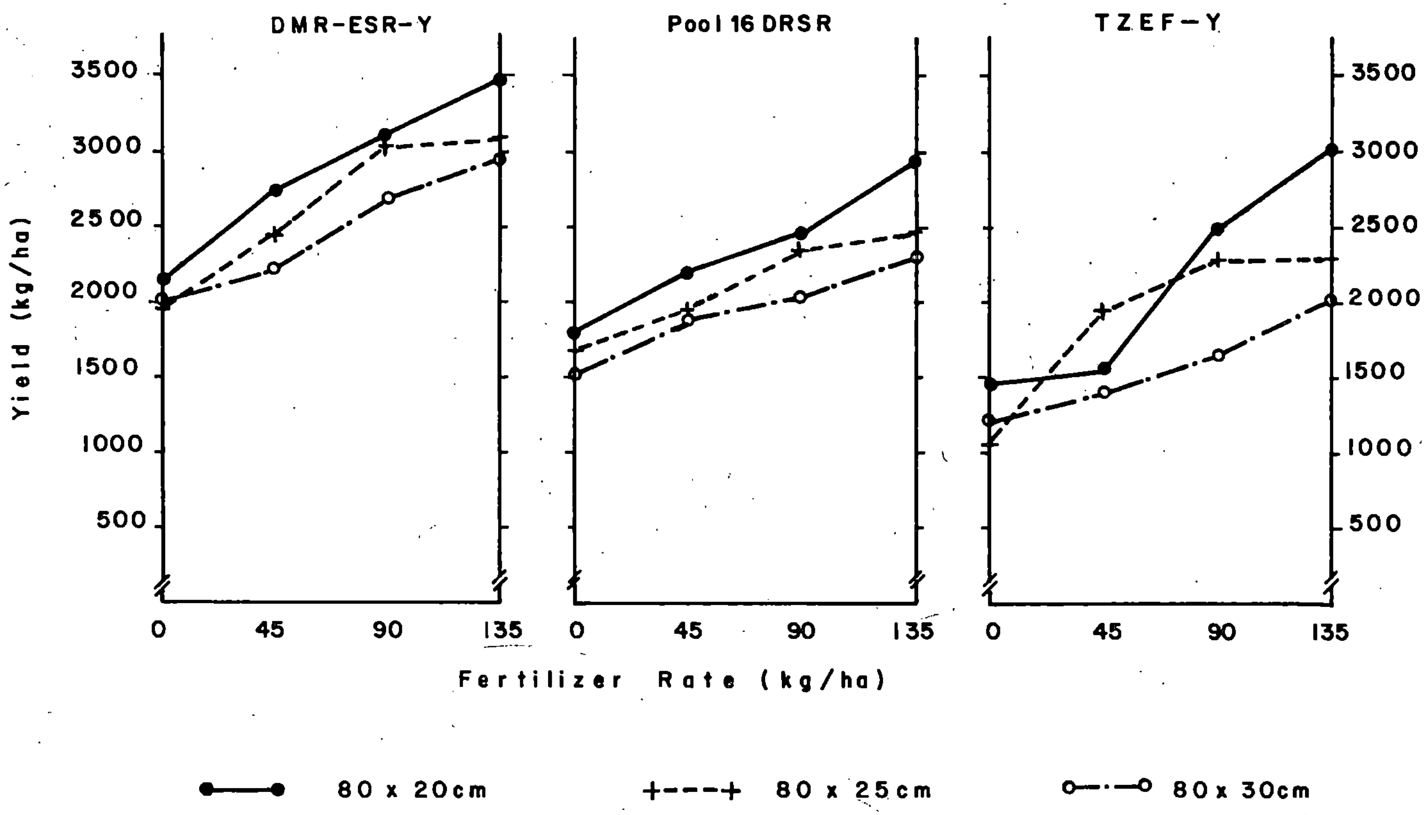

Fig. —— Effect of Nitrogen x Population densities on maize yield in Cameroon (Early and extra-early cultivars)

Table 9. Response of the early maize and local cultivar DMR-ESR-Y to two levels of N-fertilization in the Far North Province of Cameroon (1992).

Treatment Levels (T)	Average grain yield t/ha	Yield Increase t/ha Over Check	RGY %	Monetary value extra yield in FCFA
T_1 - Farmers' Variety + 100 kg/ha of compound fertilizer - NPKSB (15-20-15- 6-1)	3.27(A)	-	100	-
T_2 - Farmers' Variety improved fertilization (200 kg of complete fertilizer + 150 kg of Urea N/ha)	3.87(B)	0.60	118	+30,000
T_3 - Improved Variety-DMR-ESR-Y + 100kg/ha compound fertilizer	3.75(B)	0.48	114	+24,000
T_4 - Improved Variety + improved fertilization 200 kg/ha complete fertilizer + 150 kg Urea-N/ha.	4.57(B)	1.30	139	+65,000

Note : Treatments (T) followed by the same letter are not significant at 5% level.

C.V. 17%.

Source: (Ref. 1, 6 and 12).

iv) Summary and Recommendations.

(a) In Cameroon, improved agronomic packages (i.e, improved varieties, fertilizer, plant population, etc.) were developed for early and extra-early maize cultivars. Through the project assistance, two suitable early maturing maize cultivars namely, DMR-ESRY and Pool-16 DR-SR were released for the lowland savanna zone in Northern Cameroon. These maize cultivars have short maturity cycle (90-95 days) and potential yield of 4 to 6.5 t/ha. These varieties are appreciated by farmers due to their earliness and for use as "green maize" (within 65 days from planting) during the hunger period, before sorghum and millet harvest. For market gardeners, the sale of green maize has also become a source of income.

(b) Based on the results of on-farm verification trials in the North and Far-North Provinces of Cameroon, the following agronomic practices for the early maturing maize cultivars (i.e., DMR-ESR-Y, Pool 16 DR-SR, etc.) are recommended:

(i) Optimum plant population density of 62.500 plants/ha. Although the amount of fertilizer to be used varies with the soil fertility status, to obtain maize grain yield of about 3 t/ha, fertilizer rate of 100 kg/ha of complete fertilizer 15-20-15-6-1 (90 Nitrogen, 20 $P_2 0_5$ + 15 $K_2 0$ + 65 kg/ha and trace amounts of sulfur, boron and then use 150 kg. urea N/ha as top dress 20-25 days after planting, is proposed.

(ii) To obtain maize grain yields of 4.5-5.5 t/ha, it is suggested to apply a rate of 130 N + $50 P_2 0_5$ + 40 $K_2 0$ + 15 S kg/ha, using the same complete fertilizer (15-20-15-6-1) and split application of urea of 200 kg/ha 20-25 days after planting.

(iii) To conserve soil moisture and reduce risks of crop failure due to drought, it is suggested to construct tied ridges on sandy or sandy loan soils at about 25-30 days after maize planting.

(iv) Crop rotation of maize with leguminous crops (cowpea, pigeon peas, crotolaria, groundnut, etc.) is recommended not only to sustain the fertility of the soil, but also to reduce the problem of diseases and insect pests.

(c) The potential yield of the above mentioned cultivars under optimum agroclimatic and agronomic practices varies from 5.5 to 6.5 t/ha.

(d) Seeds of the above varieties were increased and distributed to more than 1500 farmers. The yield advantage of the improved agronomic packages over traditional farming practice was about 40% more grain yield (1.3 tons/ha) an additional income of 65 000 FCFA.

3.0. GHANA.

TECHNOLOGY OPTIONS FOR FARMER DEVELOPMENT IN NORTHERN GHANA.

In Northern Ghana, the Sudan savanna zone is more densely populated (87 people/km^2) than the Guinea savanna (20 persons/Km^2) with about 80% of the population depending on agriculture. As a result of increased population pressure, land available for agriculture is fast decreasing because permanent cultivation has replaced the fallow system that rejuvenates soil fertility. Genetic improvement of food crops, and improved husbandry practices have increased the production of food grains by more than 200% over the last 20 years.

The current project was started in 1990 with the main purpose of evaluating, under farmers' conditions, improved technologies developed in agricultural research stations in order to promote the adoption of these technologies by farmers. This was undertaken by an on-farm research (OFR) team in close association with the Crops Services Department (CSD) and the Extension Services Department (ESD) of the Ministry of Agriculture, and Non-Governmental Organizations (NGOs) involved in agricultural development in Northern Ghana.

i) Project Rationale and Scope

Continued and sustained growth of production in Northern Ghana faces a number of problems, among which, the slow pace of information dissemination (technology transfer) to small-scale farmers. Indeed, despite significant improvement of the genetic potential of crops and accompanying husbandry practices, small farmers still practise low-input sustainable agriculture based on cereal-cereal or cereal-legume intercropping. In these systems, the relative densities of the component crops are variable but they tend to depend on the quantity of seed available for sowing during the planting season. To bridge the gap between technolgoy development and adoption by farmers, OFR team tries to match the diversity of potentially available technologies on the station with their demand in farmers' fields through on-farm technology verification trials. These were carried out in Bimbilla and Wa districts of Northern Ghana.

In Bimbilla district, a region located in the normally high rainfall south-eastern sector of Northern Ghana, maize, groundnut and sorghum are the major grains grown by farmers. Traditional cropping practices in this area normally involve cultivation of yams in pure stands as the first crop in the rotation after the fallow period, followed by crop mixtures. Tillage is by hoeing, while planting is on the ridge. Groundnut is grown on top of the ridge, maize by the sides while sorghum is broadcast in the furrow, which ensures good sorghum establishment. Maize and groundnut are simultaneously planted while sorhgum is sown three weeks later. Sorghum is frequently adversely affected by mid-season drought. Cassava and pigeonpea are normally planted in the periphery of the farm; other minor crops are millet and bambara nuts.

The high rate of migration into this district has caused a rapid increase in the population density of the area with the effect of further impoverishing soils. Under such circumstances, a need exists for improved and low-cost agronomic practices that will help maintain fertility levels and sustain crop production and, thereby, reduce the practice of shifting cultivation. The specific objective of technology verification trials in this area was to compare the yields of maize, groundnut and sorghum in the alleys of pigeonpea *(Cajanus cajan)* with those of the traditional practice.

In Wa district (Upper West Region), rapid increase in the cost of compound ferti lizers (e.g. 15:15:15 or 20:20:20) led farmers to buy slightly cheaper straight fertilizers (urea, etc.). However, nutrient deficiences of soils in this area and other parts of Northern Ghana include not only nitrogen but also phosphorus deficiency, due to intensive cultivation resulting from the elimination of the practice of fallowing.

The most common land preparation methods are flat cultivation, ridge and mound construction. Ridges are sometimes tied whereas mounds are discrete units resulting from the collection of the topsoil in a particular area. On-farm technology verification trials were carried out in this region with the specific objective of determining which of these traditional tillage practices optimizes phosphorus availability and utilization by crops.

Throughout the Upper West Region of Northern Ghana, farmers commonly grow cerea-legume mixtures. On-farm verification activities were therefore launched in this region to identify compatible crops for efficient intercropping and rotation schemes. Alley-cropped fields were sited close to farmers' fields of the same crops. Maize and sorghum were planted at a total density of about 60 000 plants/ha in a 1:1 ratio. Planting density for groundnut was 120 000 plants/ha and population density for pigeonpea was 6800 plants/ha. Harvest was done on a 22 m x 6 m area randomly chosen in the alley cropped plot within the farmer's field. Yield in the alley-cropped plots were calculated as the ratio of the produce of each crop to the total harvest area. In the succeeding years, the part of the alley plot planted to cereals was planted to groundnut and vice versa. Pigeonpea was pruned in the second year and was used as much/manure on the plots previously planted to groundnut and was to be planted to the cereals.

ii) **Improving Alley-Cropping Systems.**

In ten villages of Bimbilla district, the benefit of growing maize, sorghum, and groundnut between alleys of pigeon pea was investigated. Plant stands, especially those of maize, were poor and variable in farmers' fields. The ratio of the component crops was dictated by farmers' preference and availability of seed during planting.

The data indicated that the average yields achieved under alley cropping for maize (2341 kg/ha) and groundnut (816 kg/ha) were 188 % and 54 % higher than those obtained under farmers' practice (Table 10). There was no significant difference between these cropping methods for sorghum yields in both seasons, and for groundnut yield in 1990. However, alley-cropped groundnut produced higher yields in 1991 than under farmer's practice.

Table 10. The effects of alley-cropping with pigeonpea on the grain yields (kg/ha) of maize, sorghum and groundnut in Northern Ghana.

Crops	Without Alley-Cropping			Alley-Cropping			C.V. %		LSD.05	
	1990	1991	Mean	1990	1991	Mean	1990	1991	1990	1991
Maize	608	1019	814	1812	2870	2341	23	25	880	989
Sorghum	503	752	628	258	971	615	21	22	267	NS
Groundnut	461	600	531	422	1210	816	26	29	341	588

Source: (Ref. 1, 6 and 11).

It is noticeable that in 1991, the yields of all three crops in the alley cropped plots increased significantly compared to 1990, due to the combined effects of better rainfall, rotation within the alley cropping and the mulch benefits from the pigeonpea. The pigeonpea variety used (Wantugu pink) was an improved local variety whose seed the farmers immediately planted on their own fields. The prospects of alley farming with pigeonpea in the district is high if the farmers would prune the alleys before planting the other food crops.

iii) The Effect of Tillage Practices on the Availability of Phosphorous.

In two villages of Wa district, different tillage practices for optimum phophorus incorporation and for beneficial residual effect for succeeding crop was investigated. Sorghum planted two weeks after maize suffered from drought. Germination was poor, despite efforts to refill the gaps. Therefore, no difference was observed between treatments for sorghum yields.

On-farm research in the past three years (1990-92) indicated that moisture retention and physical attributes of the soil were improved with mounding, which might have increased phosphorus nutrition for maize. This was due to the fact that mounding increased the depth of the soil, which enhanced root penetration and resulted in better utilization of soil moisture and nutrients in the rhizosphere. As a result, mounding gave the highest yield (1228 kg/ha), that is, 24% more than ridges (994 kg/ha) and 61% more than flat cultivation (763 kg/ha) with the addition of 20 P_2O_5 kg/ha (Table 11). Without phosphorus, mounding produced 1035 kg/ha, that is, 60% more than ridges (646 kg/ha) and 48% more than flat cultivation (699 kg/ha).

Regardless of the tillage method used to incorporate phosphorus (P) into the soil, low amounts of rainfall in the 1990 season impeded P movement in soil; therefore, its addition did not have any significant effect on grain yield. In the 1991 cropping season there was a better rainfall, thus, the residual effects of the P fertilizer added the previous year were apparent in the significant increase of yield of maize grown on mounds or ridges. No P effect was found for maize grown on the flat.

Although this experiment was conducted over a small number of years, it has shown that P should be added to the soil at least every third year. A good rainfall distribution is needed for a significant expression of added P. Among traditional tillage practices, mounds and contour ridging should be encouraged with the suggestion that they be tied to prevent soil erosion.

Table 11. The effects of tillage practices and Phosphorus application on the yield of maize (kg/ha) in Northern Ghana.

Tillage Practice	Phosphorus (P_2O_5 kg/ha)	Yield kg/ha			
		1990	1991	1992	Average
Ridges	0	496	621	822	646
	20	331	1912	739	994
Mounds	0	849	1434	822	1035
	20	925	2032	728	1228
Flat	0	344	796	958	699
	20	389	880	1021	763

Source: (Ref. 1, 6 and 17).

iv) Cereal-Legume Rotation.

Cereal/legume mixtures and rotation are practices used by farmers since crop rotation has the potential of maintaining soil fertility while controlling weeds in addition to its impact on the yield and economic output of the component crops. In Upper West Region of Ghana, compatible crop associations and rotation systems were studied involving 70 farm households in 14 villages. Maize and groundnut yields in the rotation plots were significantly higher than in farmers' plots (Table 12), both in 1991 and 1992. Sorghum yields also increased (1058 kg/ha) in 1992. The average yields obtained following rotation were 2719 kg/ha for maize, 948 kg/ha for sorghum and 1555 kg/ha for groundnut and the corresponding yield increase over farmers' practice for maize, groundnut and sorghum was 36%, 88 and 30%, respectively. Without rotation, maize yield declined from 2867 kg/ha the first year to about 913 kg/ha the third year; while groundnut yields also decreased from 897 kg/ha in 1990 to 552 kg/ha in 1992 and sorghum yields changed slightly during the same period.

Table 12. The effect of crop rotation on grain yield of cereals and legume component (kg/ha).

Crop	Yield kg/ha rotation plots				Yield in kg/ha (Farmers' practice)			
	1990	1991	1992	Average	1990	1991	1992	Average
Maize	2758	3150	2250	2719	2867	2235	913	2005
Sorghum	863	923	1058	948	677	698	816	730
Groundnut	2071	1652	943	1555	897	1027	552	825

C.V.% Maize 20, 22 and 18% for 1990/91/92, respectively.
Sorghum 28, 19 and 20% for 1990/91/92 respectively.
Groundnut 28, 19 and 20% for 1990/91/92, respectively.

Source: (Ref. 1, 6 and 11).

v) **Summary and Recommendations.**

(a) In Northern Ghana, various cropping systems were evaluated. For example, in Bimbilla district, involving ten villages and 35 farmers, the grain yields of maize and groundnut under alley cropping system (including cereal/pigeonpea), increased by 188 and 54%, respectively, than traditional farmers' practices.

(b) In favourable moisture conditions, in the Bimbilla district, alley cropping with pigeonpea (combined with cereal-legume rotation) sustained soil fertility and, thereby, crop productivity in the area. This will in turn reduce the need to clear virgin lands each year, an ecologically dangerous practice.

(c) In good rainfall years, both mounds and ridges impart good physical characteristics to the soil, which makes crops responsive to the application of phosphorous. Under poor rainfall conditions, mounds still improve crop yields. Thus, mounding and ridge tillage practices are used by farmers.

(d) Cereal-legume rotation has been shown to improve component crop yields by at least 30% over continuous cropping, due to its effect in maintaining soil fertility while controlling weeds.

Double cropping of legumes and cereals should be encouraged since this practice was shown to improve farmers' production without expanding the area under cultivation in the same year, especially in areas with well defined rainfall patterns.

4.0. MALI.

IDENTIFICATION AND AGRONOMIC EVALUATION OF MAIZE CULTIVARS SUITABLE FOR SEMI-ARID REGIONS.

Maize is the third important cereal essentially used for human consumption in various forms in Mali. Over 50% of the maize is cultivated in the cotton production region. In the past ten years, there has been substantial increase in maize production in Mali from 38,000 ha in 1980 to 130,000 in 1992. Yield per unit of land has also increased by 52% during the same period (Table 13).

Under farmers' conditions, maize is grown in association with millet, cowpea or in a rotation with cotton. The principal constraints to maize production include poor soil fertility, particularly the availability of nitrogen and phosphorus; and the lack of suitable varieties adapted to different ecological zones.

The purpose of verification trials on maize has been, first, to identify suitable early and extra-early maize cultivars and to develop improved agronomic packages for the semi-arid ecologies in the Sudano-Guinean zone.

i) Project Objectives.

- To test local and introduced improved maize varieties from SAFGRAD and other sources under different agroecological conditions;

- To minimize the effects of environmental and biotic constraints to maize production in the region;

- To identify and develop suitable maize varieties for the Sudanian zone.

ii) High Yielding, Early Maturing Maize Cultivars were Identified.

The initial phase (1990) of the verification trials consisted of evaluating severalmaize varieties on research stations. Two different maize maturity groups were studied namely: extra-early maturing (90-95 days to maturity), and intermediate maturing cultivars (100-120 days to maturity).

Twelve (12) elite extra-early maize cultivars and a local variety were evaluated at two locations, Katibougou (760 mm, rainfall) and Massentola (760 mm, rainfall). Furthermore, 13 early-maturing maize cultivars and a local check were evaluated at Sotuba (830 mm, rainfall), and Kita (770 mm, rainfall).

Table 13. Maize production trends in the major agricultural development zones of Mali*

Year	CMDT			OHVN			ODIMO			Total production		Average yield kg/ha
	Area ha	Production ha	yield kag/ha	Area ha	Production tons	yield kg/ha	Area ha	Production tons	yield ka/ha	ha	tons	
1980	24 302	34 023	1 400	7 100	9 214	771	6 725	6 700	850	38 127	49 962	1 007
1982	27 230	40 845	1 500	12 037	13 097	919	1 543	1 277	828	40 810	55 219	1 082
1984	38 167	50 075	1 312	12 811	14 218	855	11 733	10 700	786	62 711	74 993	984
1986	53 496	104 964	1 962	12 163	18 973	1 470	15 497	24 685	1 593	81 156	148 622	1 675
1988	63 750	117 135	1 837	11 675	14 127	1 210	17 097	21 968	1 285	92 522	153 228	1 444
1990	80 592	156 220	1 939	11 775	12 510	1 082	21 230	28 235	1 330	113 577	196 965	1 450
1992	94 420	191 891	1 859	11608	14 931	1 286	23 052	33 655	1 460	129 080	240 477	1 535

CMDT : Compagnie Malienne pour le Développement du Textile
OHVN : Office de la Haute Vallée du Niger
ODIMO : Office de Développement Intégré du Mali Ouest

Source: (Ref. 1, 2 and 6).

Ten intermediate maize cultivars were evaluated at Longorola (990 mm, rainfall) and Sotuba. Top yielding cultivars from the three different maturity groups were promoted to verification trials on farmers' fields as follows: The three promising varieties were evaluated with local and improved check cultivars involving 37 farmers in three major ecological maize production zones (i.e., South, West and Central regions of Mali).

As summarized in Table 14, the average yield of improved maize cultivars under farmers' conditions has been 4.2 t/ha for EV8422SR, a medium-maturing maize cultivar; 3.68 and 2.31 t/ha for DMR-ESR-Y and TZESRW early and extra-early maturing cultivars, respectively. These on-farm trials were managed by the farmers themselves. In the case of the variety EV8422SR (100-120 days to maturity), its yield performance under farmers' conditions was 91% of its yield performance at the research station. The variety DMR-ESR-Y, an early maturing cultivar, gave 30% more yield than the check variety (TZESW). On the other hand, the extra-early maturing cultivar TZEF-Y gave a yield of 2.31 t/ha under farmers' practice, which was 70% of its yield potential on-research station. These data show that not only maize yields between on-station and on farmers' fields can be narrowed, but can also double or triple the productivity of farmers. Within the intermediate-maturing maize cultivars, the yield of a selected cultivar (E8422SR) and improved check (Tuxpeno-1) was only 13% higher than the local check (Tiemantie) in the southern zone of Mali. The early and extra-early cultivars evaluated in the Western and Central regions of Mali have similar trends in yield performance. In this zone, the improved variety gave yields not more than 12% of local check cultivars.

The Mali National Research System, in collaboration with various rural development agencies and through the support of this project, has identified the following maize cultivars that are released or are at pre-release stage :

Cultivar	Days to Maturity	Seed Color	Potential Yield (t/ha)
i) EV 8422-SR	115-120	White	5 to 6.5
ii) SUWAN	115-120	Yellow	6 to 7.0
iii) TZESR-W	80-90	White	3 to 5
iv) DMR-ESR-Y	80-90	Yellow	4 to 5
v) TZEF-Y	75-80	Yellow	3 to 5

Table 14. Yield (t/ha) of some maize cultivars grown under farmers' practice in the three major regions of Mali

Zones of Maize Production	Maize maturity group	Yield t/ha		
		1991	1992	Average
Southern Region	Intermediate			
Improved variety EV8422SR	"	4.46	3.93	4.2
Improved check - TUXpeno-1	"	4.45	3.75	4.1
Local check-Tiemantie	"	4.07	3.24	3.7
Western Region	Early maturing			
Improved variety - DMR-ESR-Y	"	4.83	2.52	3.7
Improved check-TZESRW	"	3.42	2.24	2.8
Local check	"	4.32	2.37	3.3
Central Region	Extra early			
Improved cultivar-TZER-Y	"	2.53	2.11	2.3
Improved check - Zanguereni	"	2.21	1.93	2.1
Local check - Boni	"	2.39	2.08	2.2

Source: (Ref. 1, 2 and 6).

iii) Summary and Recommendations.

(a) In Mali, maize production has substantially increased in the cotton and other development zones. Agronomic evaluation among 34 maize varieties carried out in 1990, showed the varieties EV-8422-SR (115 days to maturity), DMR-ESR-Y (80-90 days), and TZEF-Y (70 days) as most promising. These varieties were retained for on-farm evaluation in 1991 and 1992. A total of 37 farmers were involved in the study. In the medium maturity class, the variety EV-8422-SR produced higher yields (4.20 t/ha) and showed good resistance to maize streak virus than the improved checks, Tiémantié (3.66 t/ha) and Tuxpeño (4.10 t/ha). On-farm verification trial yields represented, respectively, as much as 91%, 88% and 86% of the yields obtained on research station for these varieties. Thus, narrowing the "yield gap" between on-research station and farmers' fields.

(b) Four maize varieties of high yield potential were identified. These include: EV8422-SR (110-120 days), DMR-ESR-Y, early maturing (80-90 days), and extra-early cultivars TZEF-Y and TZESRW (< 70 days). In 1991 and 1992, these cultivars were compared to the local maize variety with similar cycles in farmers' fields in three different recommendation zones (South, West and Centre).

(c) EV8422-SR confirmed its yield superiority over Tiémantié and Tuxpeño n° 1, already released in this zone. The variety 22SR is streak resistant, whereas Tiemantié and Tuxpeño are susceptible, resulting in reduced yields due this disease. DMR-ESR-Y confirmed its good yield performance across the years and adaptation zones. It is excellent for sale as "green maize" because of its preferred taste and acceptance. TZEF-Y, on the other hand, is highly appreciated by farmers because of its earliness; it is grown in zones of drought stress.

5.0. NIGER.

EVALUATION OF IMPROVED PACKAGES OF AGRONOMIC PRACTICES TO ENHANCE PRODUCTION OF MILLET/SORGHUM MIXED CROPPING SYSTEMS.

i) Traditional Cropping Systems

In Gaya area of Niger, eleven volunteer farmers were identified following two meetings with peasant farmers and extension representatives. Discussions were centred on traditional and improved technologies as well as developing farmers' awareness in participation to conduct trials following recommended farming practices.

The farmers involved in the project are located in Sokondjii Biirni village, 10 km from Gaya (300 km south of Niamey). Situated in the Sudan savanna, the village has sandy soil and an annual average rainfall of 750 mm.

Maize and rice are cultivated to some extent. The main legume is groundnut grown in pure stand or in mixture with cereals. Cowpea is also grown as a secondary crop within the cereal-based system. Yield of millet and sorghum (in mixture) average 700 and 250 kg/ha, respectively.

Millet is frequently relay-cropped with sorghum but some farmers relay-crop early millet with late millet. There was no evidence of noticeable use of organic manure. Crop residue is used both as animal feed and sometimes as construction material. Traditionally, the farmers do not apply any fertilizers, nor do they employ any crop protection measures, apart from hoeing and hand-pulling to remove *Striga* and other weeds. Labour is provided mostly by members of the family but some farmers hire labour. Oxen are used mostly for carting humans and farm produce. The number of farming families within the project area is estimated to be about 2000. Each family, on the average, comprises seven members.

ii) The Effect of Fertilizer Application on Yield of Millet, Sorghum and Cowpea was Investigated.

The trials consisted of: mixed planting of traditional sorghum and millet cultivars (T_1); cultivation of same cultivars with the application of fertilizer 20 kg P_2O_5 and 46 kg N/ha (T_2); mixed planting of improved cultivars of sorghum and millet without fertilizer (T_3); mixed planting of improved cultivars of same crops with application of phosphate fertilizer (T_4); and with the application of both nitrogen and phosphate fertilizer on improved cultivars (T_5).

In general, the response to fertilizer of both local and improved cultivars of millet and sorghum was positive. Millet and sorghum were cultivated in mixture. The application of 20 kg/ha P_2O_5 and 46 N/ha increased the yield of local cultivars of millet from 860 to 1200 kg/ha; and that of sorghum from 280 to 630 kg/ha (Table 15). It is important to note, however, that the improved millet (CIVT) and sorghum (BKC) varieties gave lower yields than local cultivars without fertilizer application on farmers' fields. The application of fertilizer improved yield of millet cultivars from 610 to 1115 kg/ha. Sorghum yield also increased from 395 to 708 kg/ha at the same level of fertilization.

In the arid and semi-arid regions of Niger, fodder production is an essential component of the traditional farming system. Improvement of soil fertility with the application of nitrogen and phosphorus fertilizers improved the yield of the crop residue of the traditional millet and sorghum mixed cropping system on an average of 2.7 to 4.6 t/ha. There was a slight increase in crop residue production with improved millet and sorghum mixed cropping systems even without the addition of fertilizer (Table 15). Mixed cropping of cowpea with millet or sorghum is known to produce fodder of about one ton per hectare. Proper management and utilization of crop residue, could enhance integration of livestock into the existing system of crop farming. The application of fertilizer substantially increased the production of crop residue of local over improved sorghum and millet cultivars.

The cost of production and net return of the traditional and improved agronomic practices discussed above were estimated, taking into consideration the price of inputs (fertilizer, seeds, insecticides, fungicides, etc), labour (seeding-planting, weeding, application of fertilizer, harvesting, etc.) and market prices for farm produce (grain of millet, sorghum, cowpea, etc.).

The gross revenue obtained from growing traditional millet and sorghum cultivars in mixture without fertilizer and that of improved millet and sorghum cultivar with application of fertilizer (20 kg P_2O_5 + 46 kg. N/ha) was 54670 and 109,800 FCFA, and the net revenue was about 38,000 and 70,000 FCFA/ha (Table 16), respectively. While there was an increase of revenue with the improvement of agronomic packages of the millet/sorghum/cowpea intercropping system, examination of the net return showed highest marginal rate of return up to 252% with agronomic option using local millet/sorghum mixed cropping systems with the application of the above mentioned rate of fertilizer. Mixed cropping of improved varieties gave 25% more yield than traditional cultivars with the same level of nitrogen and phosphorus fertilizer application.

Table 15. The effect of agronomic practices on the grain yield of sorghum and millet (kg/ha) on farmers' fields in Niger.

Treatment (Explained in text)	Sorghum		Millet		Millet/sorghum combined yield		Dry matter (DM) yield in kg.		Average
	1990	1991	1990	1991	1990	1991	1990	1991	
T_1	280	250	860	660	1140	910	2960	2380	2670
T_2	630	440	1200	1040	1830	1480	4030	5250	4640
T_3	420	370	600	620	1020	990	2280	2190	2235
T_4	580	600	740	890	1320	1490	2860	2740	2800
T_5	715	700	1080	1150	1795	1850	3970	3310	3640
CV%	25.15	25.0	14.84	17.0	-	-	13.0	16.0	
LSD (5%)	119.97	120.0	120.5	120.0			40.7	443	

Source: (Ref. 1,5 and 6).

The yield of the combined mixed millet/sorghum traditional cultivars was improved by 62% with the application of nitrogen and phosphorus fertilizer. On the other hand, the combined yield of mixed millet and sorghum cropping of improved cultivars increased substantially from 990 to 1850 kg/ha with the application of 20 kg P_2O_5/ha and 46 kg N/ha (Table 15). It can be concluded from this study that: (i) there was very little yield difference between improved and traditional millet and sorghum cultivars; (ii) low soil fertility, particularly lack of nitrogen and phosphorus, limited the increased production and productivity of these cereals; (iii) in 1990, moisture stress also contributed to low yields of millet and sorghum; and (iv) through manipulation of improved agronomic practices, the farmer could double or triple the yields of existing millet and sorghum cultivars.

Table 16. Gross revenue of agronomic practices (treatments) on farmers' fields in the mixed cropping millet and sorghum systems.

Treatments (T)	Yield kg/ha		Gross revenue FCFA/ha		Total cost /ha	Total	Net revenue cfa/ha
	Millet	Sorghum	Millet	Sorghum			
T_1. Mixed cropping of traditional sorghum and millet cultivars without fertilizer	660	250	40920	13750	16346	54670	38324
T_2. Mixed cropping of traditional millet and sorghum cultivars + fertilizer (20 kg P_2O_5/ha + 46kg. N/ha)	1040	440	64480	24200	25226	88680	63906
T_3. Mixed cropping of improved millet CIVT-cultivar and sorghum variety BKC without fertilizer	620	370	38440	20350	21604	58790	37186
T_4. Same as T3 + 20 kg P_2O_5/ha	890	600	55180	33000	26208	88180	61972
T_5. Same as T_4 + 46 kg N/ha	1150	700	71300	38500	39605	109800	70195

Source: (Ref. 1, 5 and 6).

iii) Summary and Recommendations.

(a) In Niger, the emphasis of the study has been to improve the productivity of the millet/sorghum-based system. Traditionally, farmers rarely apply commercial fertilizer or organic manure. The trials consisted of mixed planting of traditional and improved sorghum and millet cultivars with and without fertilizer application.

The results of this verification trials indicate that:

- The yield response of sorghum and millet to phosphate and nitrogen fertilizers was positive. Yield of these crops on farmers' fields both with local and improved cultivars either doubled or tripled.

- Intercropping of millet and sorghum or legume could also improve the productivity per unit area by 50 to 75%.

(b) Because of its importance in the Gaya region, millet/sorghum intercropping is a system which enables farmers to obtain not only two cereal productions but also much fodder for their livestock. Two years of trials have revealed that yields could be increased by, at least, 50% through slight modifications of the traditional system.

(c) The highly significant effect of phosphorous and nitrogenous fertilizers has been particularly demonstrated. Similarly, it has been observed that substantial yield improvement could be achieved by increasing plant population per hectare. Indeed a 40% yield increase has been recorded without fertilizer application.

(d) Economic analysis showed that the best production option for the farmer in the project target region would be to improve his traditional system by adopting mineral fertilization. Economic analysis (Table 16) showed susbstantial returns of economic remuneration due to fertilizer use with local millet/ sorghum mixed cropping systems, whereas, mixed cropping of improved millet/ sorghum generated slightly lower economic remuneration.

6.0. NIGERIA.

ON-FARM AGRONOMIC TESTING OF APPROPRIATE TECHNOLOGY TO INCREASE YIELD OF SORGHUM/MILLET/COWPEA CROP ASSOCIATIONS.

i) Background of Project Area

Agriculture is the primary occupation of more than 80% of the population, particularly in the north-west of Nigeria, comprising Kebbi, Sokoto, Katsina, Kaduna, Kano, Jigawa and Bauchi States, where the current project was conducted. Approximately 27 million people inhabit the region. In the northern Guinea savanna, the cropping season starts in May and lasts for 140-200 days with an annual rainfall of 900-1200 mm. In the Sudan savanna, the season starts in June and its length varies from 95 to 140 days with a total rainfall of 600-900 mm. Continuous cropping is practised on farms near the homesteads with the addition of organic manure and inorganic fertilizers, while outlying farms restore the fertility of the soil by fallowing the land for variable durations. Estimates of crop production in Nigeria stood at about 5 million Mt for sorghum; 4,594,000 Mt for millet; about 2,130,000 Mt for maize, and about 2 million Mt for beans (FAO, 1991).

The major crops in the Sudan savanna are millet and cowpea. Groundnut, sorghum and cotton are also cultivated in the northern sector of the Sudan zone, in addition to crops like cassava, sugarcane and maize that are grown only near dwellings.

The cropping systems of the Northern Guinea savanna are dominated by sorghum, millet, maize and cowpea. Other crops grown in the region include daura millet, yams, sweet potato, groundnut, cocoyam, cassava, rice and cotton. Sugarcane production is confined to hydromorphic soils. Also grown in hydromorphic soils are yam and cocoyam which are planted on ridges in association with rice in the furrows. Millet is always the first crop to be planted at the onset of rains while cotton is usually sown after food crops. Important crop mixtures in the Northern Guinea savanna include sorghum/millet, maize/sorghum, maize/cotton, sorghum/cowpea and maize/rice.

The major constraints of food production include drought stress, low soil fertility, diseases, insects and parasitic weeds. The socio-economic constraints are lack of credit, inadequate seed supply, and fertilizer. Available technologies to partially alleviate these constraints include improved cultivars and agronomic practices.

Failure of farmers to adopt new technologies may be attributed to the fact that these technologies were developed under the sole cropping system, whereas most of the farmers cultivate their crops in mixed and relay systems of various combinations. Improved variety as a component technology could tremendously benefit the farmers at least cost, but most of them currently grow traditional varieties. Also, the use of adequate amounts of fertilizers could significantly raise the productivity levels of traditional farming.

ii) On-Farm Verification Trials

Based on research station results, cowpea variety SAMPEA-7, sorghum variety KSV8, and millet variety SE13 were selected for on-farm trials. The trials were conducted in the villages of Yandoto (Sokoto State, about 200 km from Samaru), Malumfashi (Katsina State, 150 km from Samaru), and Makarfi (Kaduna State, 70 km from Samaru) in 1991. In 1992, another location, Zogarawa (Kano State, 180 km from Samaru) was used in lieu of Malumfashi.

The intercropping trials comprised local varieties of sorghum, millet and cowpea, and improved cultivars of sorghum (KSV8), millet (SE13), and cowpea (SAMPEA-7).

The field trial was conducted during the 1990 and 1991 wet season at Samaru, in the northern Guinea savanna ecological zone of Nigeria on a well-drained ferruginous tropical soil. Two varieties of maize (TZBSR and Ag-Kaduna 'hybrid) and four of cowpea (SAMPEA 1 - IAR 339-1, SAMPEA 6 - IAR 1696, SAMPEA 7 - IAR 48' and Farmer's variety) were compared in all possible combinations. The cowpea cultivars SAMPEA 1 and SAMPEA 7 are photo-insensitive, white and brown seeded, respectively, while SAMPEA 6 and Farmer's variety are photo-sensitive and white seeded types.

Two weeks after sowing, maize received 60 kg N, 60 kg P_20_5 and 60 kg K_20/ha as NPK (15-15-15) compound fertilizer. A top dressing of 60 kg N/ha as calcium ammonium nitrate (26% N) was applied to maize plants at six weeks after sowing. Fertilizer was applied by placement alongside stands of maize. No fertilizer was applied directly to intercropped cowpea while sole cowpea received 36 kg P_20_5/ha as single super phosphate (18% P_20_5). In sole and intercrops, cowpea insect pests were controlled with three applications of a tank mixture of 50 a.i./ha cypermethrin (Cymbush 10EC) with 250 g a.i./ha dimethoate (Perfekthion 40EC).

As summarized in Table 17, the average yield of sole and intercropped, hybrid maize, Ag-Kaduna was significantly higher than the open pollinated variety TZB-SRW. The average grain yield of the hybrid maize was 4.9 ton/ha and that of TZBSRW varied from 3.9 to 4.5 t/ha for sole and intercropping systems, respectively. The average yield (1990/91) of sole cropped cowpea for SAMPEA-6 (farmers' local), SAMPEA-7 and SAMPEA-1, was 1022, 977, 939 and 810 kg/ha, respectively.

Maize yields were not statistically different in 1991, unlike in 1990 when the hybrid Ag-Kaduna outyielded the open pollinated variety TZB-SRW. Maize yield was not affected by the associated cowpea cultivar in both seasons. Intercropping significantly depressed cowpea yield relative to sole cropping, with a mean reduction of 81% in 1990 and 65% in 1991. None of the improved varieties significantly outyielded the local check in both seasons, regardless of the cropping pattern (Table 17).

Furthermore, research trials at Samaru revealed that maize responded to N and P fertilizers up to 150 kg, N and 17 kg P_2O_5/ha. Grain yield of maize and cowpea were not affected by potassium. As shown in Table 18, maize yield (TZB-SRW) increased from an average yield of 567 to 3540 kg/ha with the application of 75 kg.N/ha. Doubling nitrogen application (150 kg.N/ha) increased maize yield by 20%. Further increase of nitrogen depressed yield of maize. Maize also responded positively to phosphorus fertilization up to 40 kg. P_2O_5/ha where yield improved from 2790 to 3169 kg/ha. There was also slight yield response to phosphorus application on cowpea.

Small scale farmers are the major producers of food. But improved varieties and related technologies have often been developed under sole cropping systems even though most farmers cultivate their crops in mixed and relay cropping systems.

The main objective of this investigation, therefore, has been to determine the performance and acceptibility of improved varieties of sorghum, millet, and cowpea as compared to the farmers' cultivars. For sorghum the improved variety used was KSV8 (medium cycle maturing cultivar), while the local cultivar Farafara was used for comparison. For millet, Samaru Early 13 (SE13) an improved cultivar was compared to local cultivar Zongo. Three improved cowpea varieties included for the study were Kano 1696, SAMPEA-7, and IT 845-2246-4, a multiple pest and disease resistant variety.

A total of 25 farmers were selected on expressed interest after appraising them about the project objectives through initial pre-season village meetings at each project location. In 1991, these locations were Yandoto in Sokoto State (about 200 km from Samaru) in the Sudan/northern Guinea, Malumbashi in Katsina State (about 150 km from Samaru in the Sudan/northern Guinea) and Makarfi in Kaduna State (about 70 km from Samaru) in the northern Guinea savanna agroecological zones. In 1992, the locations were again Yandoto, Makarfi but Zogarawa in Kano State (about 180 km from Samaru) was used as a replacement for Malumfashi. Two years on-farm verification trials data was obtained only at Yandoto.

In general, KSV8, an improved sorghum cultivar outyielded (1379 and 2489 kg/ha in Samaru and Yandoto in 1990 and 1992, respectively) the local Farafara (1189 and 2110 kg/ha at Samaru and Yandoto, respectively) while the main effects of cowpea variety and millet variety were not significant. In 1991, the local sorghum cultivar (Farafara) outyielded improved KSV8 sorghum by about 35%. The improved millet cultivar SE-13 significantly outyielded (1842 kg/ha) the local millet cultivar Zango (1310 kg/ha) in 1992 at Yadonto. However, millet grown with KSV8 sorghum gave a yield (1184 kg/ha) significantly higher than with Farafara (1052 kg/ha) - (IAR/SAFGRAD-Review of Research Report 1989-1992).

iii) Farmers' Perception and Acceptance of Technology.

Considering farmers' perception of the project, a higher percentage of the farmers recognized improved varieties of sorghum and cowpea variety SAMPEA-7 mostly because of the grain size and maturity at Zogarawa and cooking time, taste and maturity at Yandoto. All farmers at Yandoto preferred all the improved cultivars while at Zogarawa, only 35% of the farmers preferred the sorghum while about 77% preferred the millet. Farmers at Yandoto tended to prefer all the improved cultivars for the obvious reason that they obtained reasonably high yields unlike those at Zogarawa. About 42% of the farmers at Zogarawa complained that the sorghum did not produce adequate grains while 27% at each of the project sites complained that they received their seed inputs late. Farmers at Yandoto appeared to get along better with the project than those at Zogarawa. At Yandoto, all the farmers would like to get their seeds on time while most of the farmers at Zogarawa would like maize to be introduced and, at the same time, have better performing sorghum varieties introduced. At Zogarawa, 4% of the farmers would like to adopt the introduced sorghum KSV8, 19% would like the millet while all the farmers are ready to adopt the cowpea. At Yandoto 100% of the farmers would like to adopt all the introduced improved varieties. On the opinion of farmers on how they would like to grow the sorghum, millet and cowpea components, 100% of those at Zogarawa opted for sole crop of cowpea with sorghum and millet in mixture. On the other hand, 100% of farmers at Yandoto would like to continue with the cultivation of sorghum in sole crop and cowpea in relay mixture with millet.

Table 17. Grain yield (kg/ha) of maize and cowpea as influenced by sole and intercropping systems at Samaru, Nigeria.

Treatments	Sole cropping Yield kg/ha		Intercrop Yield kg/ha			
	1990	1991	1990		1991	
			Maize	Cowpea	Maize	Cowpea
Maize Variety						
TZB-SRW	3624	4316	4524	159a	4126	322a
Ag-Kaduna	5389	4444	5224	163	4393	388
SE +	247	300	198	13	247	33
LSD (5%)	1111	ns	582	ns	ns	ns
Cowpea Variety						
SAMPEA-1	738	881	4981b	153	3854b	350
SAMPEA-6	1024	930	4773	160	5128	212
SAMPEA-7	823	1055	4946	144	3854	399
Farmer's local	826	1217	4797	187	4289	459
SE +	102	96	280	18	350	46
LSD (5%)	ns	ns	ns	ns	ns	140

a : Averaged across cowpea varieties (mean effect of each maize variety on intercropped cowpea)
b : Averaged across maize varieties (mean effect of each cowpea variety on intercropped maize)
ns = Not significant.

Source: (Ref. 1, 3, 4 and 6).

Table 18. Effect of NPK fertilization on maize and cowpea grain yield (kg/ha) at Samaru, Nigeria.

Fertilizer	Treatments	Maize			Cowpea		
		1990	1991	Average	1990	1991	Average
Nitrogen: (N)	0	545	588	567	535	627	581
	75	3710	3371	3541	369	437	403
	150	4085	4414	4250	322	372	347
	225	3751	3900	3826	392	350	371
	SE +	146	145	-	18	20	-
	LSD (5%)	412	414	-	50	58	-
Phosphorus:	0	2747	2831	2789	386	421	404
	40	3160	3178	3169	320	452	386
	80	3161	3197	3179	401	447	424
	SE +	126	126	-	15	18	-
	LSD (5%)	357	ns		43	ns	-
Potassium:	0	3155	3137	3146	401	447	424
	60	2890	3000	2945	409	446	428
	SE +	103	103	-	7	14	
	LSD (5%)	ns	ns		ns	ns	
Interaction:	N x P	**	ns	**	ns		
	N x K	**	**	**	*		
	P x K	**	**	**	**		
	N x P x K	**	**	**	ns		

ns,*,** : non significant at 5% probability level, significant at 1% probability level, respectively.

Source : (Ref. 1, 3, 4 and 6)

iv) Summary and Recommendations.

(a)

The project area, in Nigeria, coverd the Sokoto, Kebbi, Katsina, Kaduna, Jigawa and Bachui States. The major cropping practices are Sorghum/millet/cowpea or Maize/cowpea mixtures. The verification trials comprised improved cowpea variety SAMPEA-7, sorghum variety KSV8, and millet variety SE13 in Yandoto area and gave yields (tons/ha) of 2.5 for sorghum 2.2 for millet and 1.3 for cowpea, respectively. These yields were 6-8 times higher than those recorded in Zogarawa area, leading to greater economic returns in Yandoto. However, the yield advantage of improved varieties over local cultivars was much higher in Zogarawa region than in Yandoto area. A total of 41 farmers participated in the operation in Yandoto (high rainfall, animal traction) and Zogarawa (low rainfall, manual cultivation) areas.

(b)

Nitrogen application of 75 kg/ha increased maize yield (C.V. TZBSRW) from 545 to 3710 kg/ha. Further increase of nitrogen more or less depressed the yield of the crop. Maize also responded positively to phosphorus fertilization up to 40 kg/h P_20_5 where yield improved from 2747 (without P) to 3160 kg/ha (with P application). Increasing potassium (K) level up to 60 kg/ha K_20, in fact decreased yield of maize from 3155 to 2890 kg/ha.

(c)

In general, N application on cowpea depressed grain yield substantially. There was positive response to phosphorus application where cowpea yield improved from 386 (without P) to 508 kg/ha (with 80 kg/ha P_20_5). Application of K only increased cowpea grain size.

7.0. SENEGAL.

VERIFICATION OF MILLET-BASED PRODUCTION AND DEVELOPMENT OF MINIMUM SETS OF TECHNOLOGICAL PACKAGES FOR INCREASING COWPEA PRODUCTION.

The important crops in general include millet, groundnuts (which accounts for more than 40% export revenue), rice, maize and cowpea. The principal crop, millet is cultivated within the isohyetes 250 to 900 mm rainfall.

As in other countries of the region, substantial gap is often observed between yields achieved on research station and on farmers' fields. Among the constraints that impede the optimum performance of technologies have been poor soil fertility and poor land use and management; the lack of financial resources to purchase inputs and slow adoption of improved agronomic practices including varieties and lack of conducive agricultural production policies.

i) Project Objectives.

The major objectives of this project are to:

(a) enhance the utilization of research results by farmers in the rural community.

(b) provide farmers with several technological options that could substantially increase production and productivity.

(c) improve working linkages between research agronomists and extension or rural development workers and farmers.

(d) verify the agronomic and economic feasibilities of technologies introduced to farmers.

The first component of the project consisted of the evaluation of the performance of two millet cultivars namely, Souana-3, in the Kaolack, Fatick region; and IBV8004 in the Diourbel Province in Central-North region. The performance of these varieties was compared with local cultivars under improved agronomic practices and traditional farming systems. Emphasis of the study has also been in determining fertilizer requirements (mineral and organic sources) for millet-based production systems, and verifying the performance of suitable cultivars to increase cowpea production.

ii) Some Technological Options to Enhance Millet Production were Identified.

Verification trials to improve millet production were conducted from 1990 to 1992 in the Central North (Diourbel and Thies region) and the Central-South (Kaolack region). In these major zones of millet production, improved technologies were compared with local cultivars under the traditional farming system.

In Centre-South Kaolack and Fatick regions of Senegal (Medina Sabakh, Diofior and Soumbel villages), the improved millet variety Souna-3 gave a yield advantage of 28% over local cultivars. At Diourbel and Louga regions (Ndiemane, Gatt, Thieytou, etc. villages) an improved millet variety IBV8004, gave slightly lower yield than local cultivars due to the problem of drought and plant establishment.

Groundnut and millet crops are prevalent in the traditional production systems of the central regions of the groundnut basin (Central, Central-North and Central-South zones). This part of Senegal provides more than 70% of the total millet production with low yields hardly exceeding 700 kg/ha. More than 90% of the cowpea production is also derived from this region and particularly from the Central and Central-North zones.

Millet is often grown as a sole crop and continuously in compound fields and in rotation with groundnut in bush fields. In the Central North, the Ndiémane-Bambey region, millet/cowpea relay cropping is practised. In the Central zone (Diofor), agriculture and livestock breeding are well integrated, with fields adequately manured by cattle each year or every two years. Elsewhere, manure is scantily applied and 80% of the farmers do not use mineral fertilizers for millet growing.

Soil preparation consists of superficial scraping with donkey traction. Dry planting is practised in the Central and Central North zones whereas further South, wet planting is the practice. Local varieties are more grown, the rate of utilization of improved varieties being only 5 to 10% with Souna-3 in the South and IBV8004 in the North. Cowpea is traditionally cultivated for grain and in locations where cattle are raised, for quality fodder.

Cereal/cowpea catch cropping is most common in the Southern and Central Southern zones of the country. But there are also some types of intercropping, the cereal and legume components of which are planted at the same time. In these cropping systems, cowpea does not receive any mineral fertilizer and often takes advantage of the fertilizers applied for the cereal. The Central North and Northern regions of Senegal cover 90% of the areas devoted to cowpea.

The results of the on-farm trials showed that in the Soulkou-loyen in Kaolack region, both Souna-3 and local varieties gave yields of 1106 and 888 kg/ha, respectively, under improved agronomic practices. Under the traditional practice, the yields of the variety Souna-3 and local cultivar were 725 and 434 kg/ha, respectively. It is evident that the yield of millet could significantly be increased if seed of the improved cultivars, fertilizer and other inputs are made available to farmers. The yield of Souna-3 was significantly higher than 1033 kg/ha across all locations. Farmers' millet cultivar also responded to improved agronomic techniques than traditional farming practices, with mean yields of 1181 and 792 kg/ha, respectively (Table 19). The results of these verification trials substantiate that the yields of millet cultivars can be increased by 30 to 70 percent using improved agronomic practices.

Regarding the cultivation of millet (mono-crop), in the Centre-South region, results from on-farm demonstration trials provided the following technical options for farmers:

a) The replacement of local millet cultivars with Souna-3, an improved variety, which gave an average yield of 1000 kg/ha under traditional farming systems.

b) Maintain the cultivation of local millet cultivar under improved agronomic practices, which gave an average yield of 1200 kg/ha.

c) Cultivation of the recommended millet variety Souna-3 under improved agronomic practices, which gave an average yield of 1500 kg/ha.

iii) **Fertilizer Reguirements for Millet-based Production Systems were Investigated.**

On-farm demonstrations on millet were carried out in Centre-South (9 sites) and Centre-North (5 sites) regions of Senegal. With the withdrawal of government subsidies to fertilizer in Senegal, this study was designed to determine if the application of mineral fertilizers can be reduced with combined application of organic manure (provided the latter is available). The trial included five levels of fertilizer rate on the yield of millet cultivar Souna-3, in the Kaolack and Fatick regions, and with the other millet variety (IBV800) in Centre-North region.

The recommended rate of fertilizer (150 kg/ha NPK 10-20-21 plus 100 kg urea/ha), in the villages of Medina Sabakh, Diofor, and Soumbel gave average yields of 1202, 724 and 1893 kg/ha, respectively. The mean yield for the three regions has been 1273 kg/ha. Reduction of the above mentioned fertilizer rate by 50% with addition of 2 tons/ha organic fertilizer gave 15% less yield about 1075 kg/ha (Table 20).

Table 19. Yield performance of millet variety Souna-3 and local cultivar under improved agronomic practices and traditional farming practice.

Location	Var. Souna-3		Local cultivar		
	IP	TP	IP	TP	Mean yield
Soulkou Loyen	1106	725	888	434	7882
Darou	1816	1463	1730	1511	1630
Paoskoto	1325	852	1175	804	1039
Diofior	2100	1455	1623	926	1526
Niakhar	1099	651	491	285	6365
Mean yield across location	1489	1033	1181	792	11239

IP = Improved Agronomic Practices
TP = Traditional Farming Practices.

Source: (Ref. 1, 6, 8 and 10).

Table 20. **Effect of mineral fertilizer and organic manure on the yield (kg/ha) of millet in different villages of Senegal.**

Level of fertilizer application	Medina Sabakh	Diofior	Soumbel	Thieytou	Ndiemane	Gatt	Average
150 kg/ha of NPK(10-21-21) + 100 kg/ha urea	1202	724	1893	923	1097	747	1098
150 kg/ha NPK (10-21-21) + 100 kg/ha urea + 2 t/ha organic manure	1300	833	2032	661	1497	968	1215
2 t/ha organic manure	810	575	1282	407	858	589	754
75 kg/ha NPK (10-21-21) + 50 kg/ha urea + 2 t/ha organic manure	995	515	1716	458	1247	1260	1032
4 t/ha organic manure	800	280	1528	377	979	736	783
CV %	18.2	31.5	7.4	19.9	22.4	29.3	
LSD 05%	326.4	301	235	212	478	475	

Source: (Ref. 1, 6, 8 and 10).

The yield of millet was generally low when organic manure was used alone. At Ndiemane and Gatt villages, the applications of 50% of the recommended rate of mineral fertilizer and 2 tons/ha organic manure gave the highest grain yield 1247 and 1260 kg/ha, respectively. Across locations in the three villages (i.e., Thieytou, Gatt, and Ndiemane), highest average yield (1042 kg/ha) was attained by the application of a high rate of commercial fertilizer (150 kg/ha NPK 10-21-21 and 100 kg/ha urea) and organic manure (Table 20). It is apparent from the data that, the Centre-North region has soils of relatively low fertility.

iv) The Productivity of the Millet/Cowpea Mixed Cropping System was Improved.

Based on the several years of research, suitable combinations of varieties for millet/cowpea mixed cropping systems were determined. The millet variety, IBV8004 mixed-cropped with cowpea varieties Ndiambour (grain type) and 58-74 (forage type) is well adapted (in Centre-South region) with relatively good productivity per unit of land. The millet variety Souna-3 intercropped with cowpea cultivar Bambey 21, gave better yield in Centre-North region of Senegal.

To improve the productivity of the millet-based system in the above mentioned regions, farmer-managed millet/cowpea mixed cropping systems trials were carried out in Kaolack, four sites; Fatick, four sites; Diourbel, two sites and Thies, two sites. The agronomic packages for the trials included fertilizer application (100 kg/ha NPK 8-18-27 and 100 kg/ha urea (split application).

With regard to millet/cowpea mixed cropping system, the on-farm verification trials data show that the cultivation of the millet variety Souna-3, alone gave the highest yield, compared to millet/cowpea mixed cropping system, which gave better yield in Fatick, Thies and Diourbel regions. To confirm these findings, further on-farm trials are being carried out on several sites in collaboration with the national agricultural extension system and NGOs.

Cost benefit analysis of the millet/cowpea mixed cropping system showed gross revenue of 107,285,000 FCFA in Thies, and 52,000 FCFA in Kaolack (Table 21). Sole cropping of millet also generated gross revenue of about 112,000 and 43,000 FCFA in Diourbel and Kaolack, respectively. In general cowpea yields were low in all trial sites (Table 22).

Table 21. **Yield performance (kg/ha) and gross revenue FCFA/ha from mixed millet/ cowpea cropping in four regions of Senegal**

Region	Millet yields and gross revenue					Cowpea (Ndiambour) yields and gross revenue					
	Yield/ha		Gross revenue FCFA/ha++			Yield/ka		Gross revenue FCFA/ha			
	Grain	Fodder	Grain	Fodder	Total	Grain	Stover	Grain	Stover	Total	Grand total
Kaolack	261	2274	18 270	11 370	29 640	NYR	1516	YNR	22 740	22 740	52 380
Fatick	736	3514	51 520	17 570	69 090	88	764	660	11 460	12 120	81 210
Diourbel	1158	2059	81 060	10 295	91 355	154	292	11 550	4 380	15 930	107285
Thies	719	2304	50 330	11 520	61 850	YNR	-	YNR	YNR	-	61 850

YNR = yield not recorded
Souna-3 was evaluated in Kaola and Fatick region
IBV8004 was evaluated in Diourbel and Thies region
Cowpea variety : Ndiambour was evaluated in the four regions

Prices used to calculate gross revenue: Millet (i) grain per kg = 70 FCFA; (ii) fodder per kg = 5 FCFA
Cowpea (i) grain per kg = 75 FCFA; (ii) fodder per kg = 15 FCFA

Source (Ref. 1, 6, 8 and 10)

Table 22. Yield Performance (kg/ha) and gross revenue FCFA/ha from sole cropping of millet and cowpea in four regions of Senegal

Region	Sole cropping of millet*					Sole cropping Cowpea var. Ndiambour				
	Yield/ha		Gross revenue FCFA/ha++			Yield/ka		Gross revenue FCFA/ha		
	Grain	Fodder	Grain	Fodder	Total	Grain	Stover	Grain	Stover	Total
Kaolack	381	3276	26 670	16 380	43 050	YNR	3039	YNR	45 585	45 585
Fatick	911	3249	63 770	16 245	80 015	268	1705	20 150	25 575	45 725
Diourbel	1410	2678	98 700	13 390	112 090	408	1674	30 600	25 110	55 710
Thies	527	1824	36 890	9 120	46 010	YNR	541	YNR	YNR	81 155

YNR = yield not recorded

* Two improved millet varieties were evaluated: (i) Souna-3 in the Kaola and Fatic regions IBV8004 in the Diourbel and Thies regions. The cowpea variety Ndiambour was evaluated in the four regions.

++ The following market prices were used to calculate gross revenue: Millet: (i) grain 70 CFCA/kg (ii) Fodder and hay 5 FCFA per kg. Cowpea (i) grain per kg : 75 FCFA (ii) Fodder per kg : 15 FCFA.

Source (Ref. 1, 6, 8 and 10)

v) On-Farm Verification of Improved Cowpea Cultivars was Carried Out.

The production of cowpea in Senegal was about 11,191 tons in 1961, on about 45,240 ha. Thirty years later (1989/90) cowpea production was sustained at about 30,000 tons/ha on 64,000 ha. The national average yield of cowpea varies from 250 to 400 kg/ha. During the last decade, high yielding cowpea cultivars and improved agronomic practices were developed and the support from this project has enhanced the transfer and adoption of cowpea production technologies by farmers.

The yield performance of four improved cultivars evaluated in the different villages of Senegal is summarized in Table 23. Across different sites B89-504, a relatively new cultivar, gave the highest average yield (720 kg/ha). The second highest yielding cultivar across villages has been the variety IS86-275 with an average yield of 620 kg/ha. At Thilmakha village all the four improved cultivars including Ndiambour (used as check variety) gave grain yield of over 600 kg/ha (Table 23).

Yield data for Thies and Dourbel regions was reported only for 1992 crop season. It was also noted that the variability of yield has not been only due to the yield performance among cowpea varieties, but also to differences in soil fertility and farmers' variability in the villages; also rainfall variation and drought stress. The yield performance of the improved cultivars in different villages indicate that the national average yield of cowpea can be doubled or tripled under improved agronomic management practices.

Table 23. Grain yield (kg/ha) performance of cowpea cultivars evaluated in some villages of Senegal (1990/92)

Village	Varieties			
	IS86-275[+++]	IS86-283[++]	B89-504[++]	Ndiambour[++]
Gatt Ngaraffe	554	583	693	544
Thies	724	641	647	879
Thilmakha	656	604	698	640
Diourbel	597	662	907	703
Sine Dieng	820	649	824	684
Sakal	367	489	550	414
Average	620	605	720	644

Average yield data of five sites within each village.

++ Cultivars evaluated for two years.
+++ Cultivars evaluated for three years.

Source: (Ref. 1, 6, 9 and 10).

vi) **Summary and Recommendations.**

(a) In Senegal, two improved millet cultivars namely, Souna-3, and IBV8004 were evaluated in Central South and North regions, respectively. The millet variety Souna-3 was compared to farmers' local variety under improved agronomic practices. With the addition of 2 t/ha of farm manure to a half dose of the recommended fertilizer rate, IBV8004, gave a yield of 988 kg/ha, 14% more than the full recommended rate of commercial fertilizer. The yield increase over traditional practice has been by more than 160%. With the same level of fertilization, the yield of Souna-3 was 159% more than that from traditional farming practice. The application of 2 t/ha farm manure alone produced 618 kg/ha for improved millet cultivars IBV8004 and 889 kg/ha for Souna-3 with 67% and 32% increase, respectively, over the traditional farming practice. These results suggest that low organic matter content has been more limiting to millet production in Northern Senegal than in the South.

(b) Millet-based cropping systems were evaluated in several regions. In Kaolack region, both yield and economic analysis revealed benefits from sole cropping of Souna-3, whereas-intercropping with cowpea (1:1 ratio) gave better results in Fatick region. In Diourbel and Thies regions, intercropping millet variety IBV8004 with cowpea variety Ndiambour (1:2 ratio) was more profitable than sole cropping. The reverse was observed with the improved millet variety IBV8004/58-74 and cowpea cultivar intercropping.

(c) Several new cowpea varieties were evaluated under farmer management in 6 villages in the Northern and Southern ecologies of Central Senegal where cowpea is widely grown. Results indicated that the best adapted introductions were varieties IS86-275 (Mouride) and B89-504 (Melakh) with average yields of 552 kg/ha and 864 kg/ha, respectively.

(d) As a result of the on-farm verification trials supported through the project, the following cowpea production technologies were recommended:

i) Two new varieties, IS86-275 (Mouride) and B89-504 (Melakh)

ii) Planting of cowpeas in lines

(e) Initial feedback information on farmers' response in four regions (i.e., Thies, Diourbel, Louga and Saint Louis), where on-farm trials were conducted, indicated their satisfaction with yield performance and quality of seed of the improved cowpea cultivars.

Furthermore, the project has established linkages with the national extension system, NGOs, (World Vision and Rodale Institute) to enhance the transfer and adoption of cowpea production technologies by farmers. Seed multiplication of improved cultivars and availability and price of insecticides are currently limiting cowpea production. Training (in collaboration with NGOs) of some extension agents and two groups of farmers was provided.

8. TOGO.

VERIFICATION OF IMPROVED AGRONOMIC PACKAGES TO ENHANCE THE PRODUCTIVITY OF SORGHUM/COWPEA MIXED CROPPING SYSTEMS.

The project is based in the Kara region, Northern Guinea savanna zone, where the yearly average rainfall is 1100-1300 mm. The estimated population of Northern Togo is about 430,000 inhabitants with a density of about 37/km^2. Sorghum millet, groundnut and cowpea are important staple food crops, but the production and use of maize has substantially increased in the past 20 years. Agriculture is the major occupation for 75% of the population in Togo.

i) **Project Objectives.**

a) To determine the adaptability of two improved sorghum cultivars under farmers' conditions in Northern Togo.

b) To evaluate the adaptability and acceptability of new (white seeded) early-maturing cowpea cultivars,

c) To identify the best combinations of varieties and improved agronomic practices for sorghum/cowpea mixed cropping systems

d) To assess the economic feasibility of cropping systems under consideration

Several demonstration trials were carried out in Agbassa, Tamberma and Koran regions. The number of sites increased from 6 to 11, and 15 in 1990, 1991 and 1992, respectively. The soils of the Northern Togo are ferrugenous alfisols with pH 6 - 7. The average rainfall of the region is about 1100 mm; temperatures could get as high as 38.9°C and as low as 16.3°C with a mean annual temperature of 26.C°.

The materials included for on-farm verification trials and recommended for farmers include: sorghum variety Framida, Striga tolerant and well adapted to the region. Its seed colour being red, has lower preference for food; large quantity of the production of this variety is used for the preparation of local beer. With high market acceptability, an improved short cycle cowpea cultivar (65 days to maturity) KVx396-4-4, white seeded, was introduced to farmers by the SAFGRAD project. It is highly appreciated for its seed quality, yield performance and complementarity with sorhgum or millet mixed cropping systems.

ii) **Improved Agronomic Practices Increased the Productivity of Sorghum/ Cowpea Mixed Cropping Systems.**

Improved agronomic packages for the sorghum/cowpea inter-cropping systems include varieties, plant population (62 500 plants/ha for sorghum and 31 250 plants/ha for cowpea in crop association; and 100,000 plants/ha for sole culture of cowpea) and application of fertilizer (100 kg/ha NPK 15:15:15 and 50 kg/ha urea), and insecticide, applied at the interval of 10 days to control insect pests on cowpea.

There was no significant yield difference of sorghum grown in association with cowpea and in mono-culture, with average yields of 854 and 954 kg/ha, respectively. The reduction of sorghum yield under mixed cropping system is minimal. On the other hand, the yield of cowpea increased by over three fold under sole cowpea cultivation than when it was grown in mixture with sorghum, with mean yields of 915 and 317 kg/ha, respectively (Table 24). Cowpea growth and production was depressed in mixed cropping system with sorghum and with the relatively high level of nitrogen fertilization.

Most farmers grow two to three crops in a mixture. The rationale (farmers' option for large scale practice of mixed cropping systems) is mainly to ensure food security at house-hold level; to sustain the fertility of the soil as an outcome of cereal/legume association; and increase productivity per unit of land for intercropping than mono-culture.

A cost-benefit analysis was compared for the three systems (pure sorghum crop, pure cowpea crop, and sorghum/cowpea mixture). The highest net income, about 116,000 CFA/ha and 93,603 FCFA/ha was realized with sole cowpea cultivation. Mixed sorghum/cowpea cropping also generated a net return of 108,000 FCFA/ha (1991) and 89,131 CFA/ha, respectively, but economic returns from mono-cultivation of sorghum was 54,000 (1991) and 62,480 FCFA/ha (1992), respectively (Table 25).

Intercropping sorghum with cowpea generated about 90% of the economic returns obtained by growing cowpea alone (pure culture). The advantage of the mixed cropping system, however, is that the farmer is secured of food supply at least for his family.

With regard to the effect of insecticide treatment on increasing cowpea yield, the data showed a significant yield difference between treatments (Table 26). Cowpea yield increased to 484 kg/ha with three insecticide spray applications compared to a yield 76 kg/ha on untreated cowpea fields. The data on economic analysis showed that, it would be advisable for the farmer to use one to two insecticide sprays on cowpea to minimize costs and concurrently sustain over 200% marginal rate of economic returns from the sorghum/cowpea mixed cropping system.

Table 24. Yield of sorghum and cowpea in mono-culture and mixed cropping systems in the Kara region of Northern Togo.

Year	Yield (kg/ha) under mixed cropping system			Yield (Kg/ha) under monoculture		
	Sorghum	Cowpea	L.E.R.	Sorghum	Cowpea	L.E.R.
1990	940	365	1.24	1080	916	1.00
1991	772	302	1.28	833	850	1.00
1992	850	286	1.18	950	980	1.00

L.E.R. - Land equivalent ratio is an indication of the agricultural productivity (crops) per unit of land.

Source: (Ref. 1, 6 and 13).

Table 25. Estimated net returns of sorghum and cowpea cropping systems

Cropping system	Yield kg/ha					
	Sorghum		Cowpea		Net return CFA/ha	
	1991	1992	1991	1992	1991	1992
i) Sorghum, 50,000 plants/ha; cultivated with cowpea, 25,000 plants ha	906	904	583	318	108020	89131
ii) Sorghum, 65,000 plants/ha monoculture	946	904	---		53667	62482
iii) Cowpea, 1000,000 plants/ha monoculture	---		1164	915	115876	93603

Average market price (1990) per kg of sorghum and cowpea in Northern Togo was as follows:

Cowpea 118 CFA/kg
Sorghum 67 CFA/kg
Fertilizer 65 CFA/kg
Insecticides 1800 CFA/kg

Source : (Ref. 1 and 12).

Table 26. The effect of insecticide treatment on the yieldof cowpea intercropped with sorghum

	Cropping system	Yield kg/ha							
		1990		1991		1992		Average	
		Sorghum	Cowpea	Sorghum	Cowpea	Sorghum	Cowpea	Sorghum	Cowpea
1	Sorghum/cowpea + 3 sprays of insecticide	1035	761	908	458	940	232	961	484
2	Sorghum/cowpea + 2 sprays of insecticide	1014	452	1027	305	934	137	992	298
3	Sorghum/cowpea + 1 spray of insecticide	1079	314	1017	239	869	87	988	213
4	Sorghum/copwea + 0 treatment insecticide	963	156	921	55	893	16	926	76
5	Sorghum monoculture	1068		948		965		994	
	Average	1032	421	964	264	920	118	972	268
	Coefficient of variation	13.39	18.78	18.41	16.54	10.8	19.7		

Source: (Ref. 1, 6 and 13).

iii) Summary and Recommendations.

(a) Two improved sorghum varieties, Framida and Malisor 84-1, were grown in sole culture or in association with cowpea variety KVx 396-4-4 with fertilizer application of 100 kg/ha NPK (15:15:15) and 50 kg/ha urea. Under monoculture, sorghum produced 954 kg/ha, which was only 12% more than its performance when cultivated in association with cowpea. In contrast, sole cultivation of cowpea increased its yield three fold over mixed-cropping. Economic analysis of the mixed cropping systems showed revenue of 89,131 FCFA/ha, about 5% less profitability than cowpea sole cultivation. Sorghum cultivation alone (monoculture) generated a revenue of 62,462 FCFA/ha. Based on the results of the on-farm verification trials, mixed cropping with sorghum and cowpea varieties mentioned above is recommended to ensure food-security and generation of income at household level.

(b) In the cereal/legume mixed cropping system, suitable combination of early maturing cowpea cultivars such as KVx 396-4-4; and early to medium maturing sorghum cultivars i.e., Framida, and Malisor-84-1 red and white seeded, respectively, were identified.

(c) While sole culture of cowpea, under optimum management and climatic conditions, generated highest net income, sorghum/cowpea mixed cropping is preferred by farmers, since it secures food supply at least for the farm household.

II. ANNEXES OF BASIC STATISTICS OF PROJECT PARTICIPATING COUNTRIES.

Unpublished data compiled from various sources
by OAU/STRC-SAFGRAD (1993).

Annex 1. Burkina Faso - Basic Statistics (Données de Base).

BASIC STATISTICS		DONNEES DE BASE
Area (km^2)	274 000	Superficie (km^2)
Population (millions)	9.0	Population (millions)
Population density (no./km^2)	32.8	Densité (habitants/km^2)
GDP (millions US dollars)	3 060	PIB (millions, dollars US)
Agricultural GDP as % of total GDP	32	PIB de l'agriculture en % du PIB total
% Active population in agriculture (in 1980)	87	% Population active engagée en agriculture (1980)
AGRICULTURE		**AGRICULTURE**
Agricultural land (% of total area)	13	Terres agricoles (% de la superficie totale)
Pasture land (% of total area)	37	Pâturages (en % de la superficie totale)
Forest and woodland (% of total area)	24	Forêts et bois (en % de la superficie totale)
Average annual rainfall (mm)	400-1200	Pluviométrie annuelle moyenne (mm)
Major crops (>100 tons)	So,Mi,Ma, Gr,Cp,Ct	Cultures majeures (>100 t)
Productivity (tons/ha)		Productivité (tonnes/ha)
Cereals	0.7	Céréales
Roots and tubers	6.0	Racines et tubercules
Irrigated land (% of agricultural land)	0.1	Terres irriguées (en % des terres agricoles)
NATIONAL RESEARCH SYSTEM		**SYSTEME DE RECHERCHE**
Number of researchers	85	Nombre de chercheurs
Number of technicians	180	Nombre de techniciens

Note: So = sorghum/sorgho, Mi = millet/mil, Ma = maize/maïs, Gr = groundnut/arachide, Cp = cowpea/niébé, Ct = cotton/coton.

Annex 2. Cameroon - Basic Statistics (Données de Base).

BASIC STATISTICS		DONNEES DE BASE
Area (km^2)	475 000	Superficie (km^2)
Population (millions)	11.7	Population (millions)
Population density(no./km^2)	24.6	Densité (habitants/km^2)
GDP (millions US dollars)	11 130	PIB (millions, dollars US)
Agricultural GDP as % of total GDP	27	PIB de l'agriculture en % du PIB total
% Active population in agriculture (in 1980)	70	% Population active engagée en agriculture (1980)
AGRICULTURE		**AGRICULTURE**
Agricultural land (% of total area)	15	Terres agricoles (% de la superficie totale)
Pasture land (% of total area)	18	Pâturages (en % de la superficie totale)
Forest and woodland (% of total area)	53	Forêts et bois (en % de la superficie totale)
Average annual rainfall (mm)	400-2000	Pluviométrie annuelle moyenne (mm)
Major crops (>100 tons)	So,Mi,Ma, Ri,Gr,Ct,Rt	Cultures majeures (>100 t)
Productivity (tons/ha)		Productivité (tonnes/ha)
Cereals	1.3	Céréales
Roots and tubers	2.6	Racines et tubercules
Irrigated land (% of agricultural land)	0.2	Terres irriguées (en % des terres agricoles)
NATIONAL RESEARCH SYSTEM		**SYSTEME DE RECHERCHE**
Number of researchers	300	Nombre de chercheurs
Number of technicians	480	Nombre de techniciens

Note: So = sorghum/sorgho, Mi = millet/mil, Ma = maize/maïs, Gr = groundnut/arachide, Ct = cotton/coton, Ri = rice/riz, Rt = roots & tubers/racines & tubercules.

Annex 3. Ghana - Basic Statistics (Données de Base).

BASIC STATISTICS		DONNEES DE BASE
Area (km^2)	239 000	Superficie (km^2)
Population (millions)	14.9	Population (millions)
Population density(no./km^2)	62.3	Densité (habitants/km^2)
GDP (millions US dollars)	6 270	PIB (millions, dollars US)
Agricultural GDP as % of total GDP	48	PIB de l'agriculture en % du PIB total
% Active population in agriculture (in 1980)	56	% Population active engagée en agriculture (1980)
AGRICULTURE		AGRICULTURE
Agricultural land (% of total area)	12	Terres agricoles (% de la superficie totale)
Pasture land (% of total area)	22	Pâturages (en % de la superficie totale)
Forest and woodland (% of total area)	35	Forêts et bois (en % de la superficie totale)
Average annual rainfall (mm)	900-1500	Pluviométrie annuelle moyenne (mm)
Major crops (>100 tons)	So,Ma,Gr, Co,Rt	Cultures majeures (>100 t)
Productivity (tons/ha)		Productivité (tonnes/ha)
Cereals	1.0	Céréales
Roots and tubers	6.2	Racines et tubercules
Irrigated land (% of agricultural land)	0.1	Terres irriguées (en % des terres agricoles)
NATIONAL RESEARCH SYSTEM		SYSTEME DE RECHERCHE
Number of researchers	90	Nombre de chercheurs
Number of technicians	315	Nombre de techniciens

Note: So=sorghum/sorgho, Ma=maize/maïs, Gr=groundnut/arachide, Rt= roots & tubers/racines & tubercules, Co=coconut/noix de coco.

Annex 4. Mali - Basic Statistics (Données de Base).

BASIC STATISTICS		DONNEES DE BASE
Area (km^2)	1 240 000	Superficie (km^2)
Population (millions)	8.5	Population (millions)
Population density(no./km^2)	6.9	Densité (habitants/km^2)
GDP (millions US dollars)	2 450	PIB (millions, dollars US)
Agricultural GDP as % of total GDP	46	PIB de l'agriculture en % du PIB total
% Active population in agriculture (in 1980)	86	% Population active engagée en agriculture (1980)
AGRICULTURE		**AGRICULTURE**
Agricultural land (% of total area)	2	Terres agricoles (% de la superficie totale)
Pasture land (% of total area)	25	Pâturages (en % de la superficie totale)
Forest and woodland (% of total area)	6	Forêts et bois (en % de la superficie totale)
Average annual rainfall (mm)	100-1300	Pluviométrie annuelle moyenne (mm)
Major crops (>100 tons)	So,Mi,Ma, Ri,Ct	Cultures majeures (>100 t)
Productivity (tons/ha)		Productivité (tonnes/ha)
Cereals	0.9	Céréales
Roots and tubers	8.5	Racines et tubercules
Irrigated land (% of agricultural land)	0.6	Terres irriguées (en % des terres agricoles)
NATIONAL RESEARCH SYSTEM		**SYSTEME DE RECHERCHE**
Number of researchers	215	Nombre de chercheurs
Number of technicians	380	Nombre de techniciens

Note: So=sorghum/sorgho, Mi=millet/mil, Ma=maize/maïs, Ct=cotton/coton, Ri=rice/riz.

Annex 5. Niger - Basic Statistics (Données de Base).

BASIC STATISTICS		DONNEES DE BASE
Area (km^2)	1 267 000	Superficie (km^2)
Population (millions)	7.7	Population (millions)
Population density(no./km^2)	6.1	Densité (habitants/km^2)
GDP (millions US dollars)	2 520	PIB (millions, dollars US)
Agricultural GDP as % of total GDP	36	PIB de l'agriculture en % du PIB total
% Active population in agriculture (in 1980)	91	% Population active engagée en agriculture (1980)
AGRICULTURE		AGRICULTURE
Agricultural land (% of total area)	3	Terres agricoles (% de la superficie totale)
Pasture land (% of total area)	7	Pâturages (en % de la superficie totale)
Forest and woodland (% of total area)	2	Forêts et bois (en % de la superficie totale)
Average annual rainfall (mm)	100-900	Pluviométrie annuelle moyenne (mm)
Major crops (>100 tons)	So,Mi,Cp,Rt	Cultures majeures (>100 t)
Productivity (tons/ha)		Productivité (tonnes/ha)
Cereals	0.4	Céréales
Roots and tubers	7.1	Racines et tubercules
Irrigated land (% of agricultural land)	0.3	Terres irriguées (en % des terres agricoles)
NATIONAL RESEARCH SYSTEM		SYSTEME DE RECHERCHE
Number of researchers	83	Nombre de chercheurs
Number of technicians	140	Nombre de techniciens

Note: So=sorghum/sorgho, Mi=millet/mil, Cp=cowpea/niébé, Rt= roots & tubers/racines & tubercules.

Annex 6. Nigeria - Basic Statistics (Données de Base).

BASIC STATISTICS		DONNEES DE BASE
Area (km²)	924 000	Superficie (km²)
Population (millions)	115.5	Population (millions)
	125.0	
Population density(no./km²)	34 760	Densité (habitants/km²)
GDP (millions US dollars)	36	PIB (millions, dollars US)
Agricultural GDP as % of total GDP	68	PIB de l'agriculture en % du PIB total
% Active population in agriculture (in 1980)		% Population active engagée en agriculture (1980)
AGRICULTURE		**AGRICULTURE**
Agricultural land (% of total area)	34	Terres agricoles (% de la superficie totale)
Pasture land (% of total area)	44	Pâturages (en % de la superficie totale)
Forest and woodland (% of total area)	13	Forêts et bois (en % de la superficie totale)
Average annual rainfall (mm)	600-2000	Pluviométrie annuelle moyenne (mm)
Major crops (>100 tons)	So,Mi,Ma, Ri,Wh,Gr, Cp, Ct, Co,Rt,Pa	Cultures majeures (>100 t)
Productivity (tons/ha)		Productivité (tonnes/ha)
Cereals	1.2	Céréales
Roots and tubers	12.4	Racines et tubercules
Irrigated land (% of agricultural land)	1.2	Terres irriguées (en % des terres agricoles)
NATIONAL RESEARCH SYSTEM		**SYSTEME DE RECHERCHE**
Number of researchers		Nombre de chercheurs
Number of technicians		Nombre de techniciens

Note: So=sorghum/sorgho, Mi=millet/mil, Ma=maize/maïs, Gr=groundnut/arachide, Cp=cowpea/niébé, Ct=cotton/coton, Ri=rice/riz, Rt= roots & tubers/racines & tubercules, Cn=coconut/noix de coco, Pa=palm tree/palmier, Wh=wheat/blé.

Annex 7. Senegal - Basic Statistics (Données de Base).

BASIC STATISTICS		DONNEES DE BASE
Area (km^2)	197 000	Superficie (km^2)
Population (millions)	7.4	Population (millions)
Population density(no./km^2)	37.6	Densité (habitants/km^2)
GDP (millions US dollars)	5 840	PIB (millions, dollars US)
Agricultural GDP as % of total GDP	21	PIB de l'agriculture en % du PIB total
% Active population in agriculture (in 1980)	81	% Population active engagée en agriculture (1980)
AGRICULTURE		**AGRICULTURE**
Agricultural land (% of total area)	27	Terres agricoles (% de la superficie totale)
Pasture land (% of total area)	30	Pâturages (en % de la superficie totale)
Forest and woodland (% of total area)	31	Forêts et bois (en % de la superficie totale)
Average annual rainfall (mm)	300-900	Pluviométrie annuelle moyenne (mm)
Major crops (>100 tons)	So,Ma,Mi, Ri,Gr,Rt	Cultures majeures (>100 t)
Productivity (tons/ha)		Productivité (tonnes/ha)
Cereals	0.8	Céréales
Roots and tubers	4.3	Racines et tubercules
Irrigated land (% of agricultural land)	1.7	Terres irriguées (en % des terres agricoles)
NATIONAL RESEARCH SYSTEM		**SYSTEME DE RECHERCHE**
Number of researchers		Nombre de chercheurs
Number of technicians		Nombre de techniciens

Note: So=sorghum/sorgho, Mi=millet/mil, Ma=maize/maïs, Gr=groundnut/arachide, R=rice/riz, Rt= roots & tubers/racines & tubercules.

Annex 8. Togo - Basic Statistics (Données de Base).

BASIC STATISTICS		DONNEES DE BASE
Area (km^2)	57 000	Superficie (km^2)
Population (millions)	3.6	Population (millions)
Population density(no./km^2)	63.2	Densité (habitants/km^2)
GDP (millions US dollars)	1 620	PIB (millions, dollars US)
Agricultural GDP as % of total GDP	33	PIB de l'agriculture en % du PIB total
% Active population in agriculture (in 1980)	73	% Population active engagée en agriculture (1980)
AGRICULTURE		**AGRICULTURE**
Agricultural land (% of total area)	21	Terres agricoles (% de la superficie totale)
Pasture land (% of total area)	33	Pâturages (en % de la superficie totale)
Forest and woodland (% of total area)	30	Forêts et bois (en % de la superficie totale)
Average annual rainfall (mm)	900-1500	Pluviométrie annuelle moyenne (mm)
Major crops (>100 tons)	So,Ma,Rt	Cultures majeures (>100 t)
Productivity (tons/ha)		Productivité (tonnes/ha)
Cereals	0.9	Céréales
Roots and tubers	8.3	Racines et tubercules
Irrigated land (% of agricultural land)	0.2	Terres irriguées (en % des terres agricoles)
NATIONAL RESEARCH SYSTEM		**SYSTEME DE RECHERCHE**
Number of researchers		Nombre de chercheurs
Number of technicians		Nombre de techniciens

Note: So=sorghum/sorgho, Ma=maize/maïs, Rt= roots & tubers/racines & tubercules.

Annex 9. List of Collaborating Institutions.

Country	National Agricultural Research Systems	Project Emphasis	Agricultural Extension and Development Organizations	Number of Project Sites.
Burkina Faso	Institut d'Etudes et de Recherches Agricoles **(INERA)**	Verification of cowpea production technologies.	Centre Régional de Promotion Agro-Pastorale (CRPA). National Agro-Pastoral Extension and Development Centre.	12 districts
Cameroon	Institut de Recherches Agronomiques **(IRA)**	Developing agronomic packages of technology for early and extra early maize cultivars in the low dry lands of North and Far-North Provinces.	SODECOTON: A parastatal company that promotes cotton-based agricultural and rural development.	15
Ghana	Nyankpala Agricultural Experiment Station, Crop Research Institute **(CRI).**	Technology Options for farmers in Northern Ghana.	i) Crop Services Department. ii) National Agricultural Extension Department.	32
Mali	Institut d'Economie Rurale **(IER).**	Identification and agronomic evaluation of suitable maize cultivars for semi-arid regions.	i) Compagnie Malienne pour le Développement Textile (CMDT). ii) Office de la Haute Vallée du Niger (OHVN). iii) Office de Développement Intégré du Mali Ouest (ODIMO).	25
Niger	Institut de Recherche Agronomique du Niger **(INRAN)**	Evaluation of improved packages of agronomic practices to enhance production of millet/sorghum mixed cropping systems.	National Extension and related rural development organizations..	2
Nigeria	Institute for Agricultural Research, Ahmadu Bello University **(IAR/ABU)**	On-farm agronomic testing of appropriate technology to increase yields of sorghum/millet/ cowpea crop associations.	i) National Agricultural Extension System (Training and Visit) ii) Agricultural Development Projects (ADP's).	9
Senegal	Institut Sénégalais de Recherches Agricoles **(ISRA).**	i) Verification of millet based production technologies. ii) Development of minimum set of technological packages for increasing cowpea production.	Farmers' organizations and non-government organizations (NGOS)	30
Togo	Direction de la Recherche Agronomique **(DRA)** Antenne Régionale SAFGRAD.	Verification of improved agronomic packages to enhance productivity of sorghum/cowpea mixed cropping systems.	i) European Fund for Development (FED). ii) Directions Régionales de Développement Rural de Kara et des Savanes.	5

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