African Journal of Agricultural Research Vol. 5(17), pp. 2297-2304, 4 September, 2010
Available online at http://www.academicjournals.org/AJAR
ISSN 1991-637X ©2010 Academic Journals

Full Length Research Paper

On-farm evaluation of improved cowpea-cereals cropping systems for crop-livestock farmers: Cereals-cowpea systems in Sudan savanna zone of Nigeria

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Accepted 4 August, 2010

From 2003 to 2005, a farmer's participatory evaluation of improved cowpea-cereal cropping systems in the Sudan savanna zone of Nigeria involving over 1600 farmers was conducted. The system involved growing improved cowpea varieties with cereal in a 2 cereal: 4 cowpea row to row arrangements, with application of inorganic and organic fertilizer to the crops and 2 to 3 insecticide sprays to the cowpea. Training was provided to all farmers and extension agents at the village level, while the farmers' group leaders and extension agents were further given on-station training. The results indicate that the improved cropping systems using improved varieties of cowpeas were superior to the traditional systems. The economic value of grains of the improved systems ranged from 160 to 680% of the traditional controls while the total produce gave gross returns of 160 to 571% of the total produce of the traditional controls in the Sudan savanna zone of Nigeria. The improved systems also produced better quality crop residues with increase in the leguminous portion of the residues and therefore likely to improve productivity of the livestock.

Key words: Cowpea-cereal systems, farmer participatory trial, improved strip cropping system, *Vigna unguiculata.*

INTRODUCTION

Nigeria, with grain production estimated at 2.8 million Mt on 4.1 million ha (FAOSTAT, 2006), is the largest producer of cowpea [*Vigna unguiculata* (L.) Walp.], in the world, yet Nigeria with a population of about 150 million people and a high growth rate imports cowpea from neighboring countries. Cowpea is an important grain legume in the savannas of West Africa providing a cheap source of vegetable protein to the urban and rural poor, as well as mineral and protein rich fodder for livestock feeding and cash to the farmers. It also provides employment opportunities to thousands of urban and rural women who prepare and sell various traditional cowpea snacks by road sides in the early mornings and evenings. Cowpea has the potential of being an industrial crop (Lambot, 2002), and with its importance in the sustainability of the cropping systems of the savannas of West Africa, increases in its productivity should be encouraged. Most of the farmers in the savannas of West Africa cultivate local varieties of cowpea, millet (*Pennisetum glaucum* L.), sorghum (*Sorghum bicolor* L.) and groundnut (*Arachis hypogea L.*) in various intercropping systems with little or no purchased inputs and therefore yields are low (Mortimore et al., 1997; Singh and Ajeigbe, 2002) due to biotic and abiotic factors. In these systems, the cowpea and groundnut yields are low due to shading by cereals and lack of plant protection measures and the cereal yields are low due to

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lack of fertilizer. This leads to a negative balance of nutrients in the soil and continuous decline in crop yields which perpetuates malnutrition, hunger and poverty through the vicious circle of low input-low production-low income. One of the major challenges before agricultural research in this region is to reverse this trend. The advantages of intercropping are many, and these include better use of available resources, yield stability, reduces crop losses due to weeds, pests, and diseases, soil fertility maintenance due to reduces erosion and nutrient leaching, and balanced distribution of labour requirement (Norman, 1974; Steiner, 1982; Ajeigbe, 2003).

A survey conducted by the International Institute of Tropical Agriculture (IITA) revealed that the cowpea grain yield under the traditional system in the Sudan savanna zone of Nigeria ranged from 0 to 132 kg/ha, groundnut grain yield ranged from 0 to 197 kg/ha, millet grain yield ranged from 131 to 2600 kg/ha and sorghum grain yield ranged from 0 to 4903 kg/ha (Henriet et al., 1996; van Ek et al., 1996). Due to increasing population in the region and resulting reduction in arable land per capita, there is a need to increase yields per unit area through improvement in the cropping systems, use of improved varieties of crops and general increase intensifications. On-station trials by IITA have shown that overall farm yields could be increased in a sustainable manner through the adoption of improved varieties, cropping pattern and crop-livestock integration. This has been demonstrated by on-farm trials of 'best-bet options' involving improved dual purpose cowpeas by IITA, International Crop Research Institute for Semi-Arid Tropics (ICRISAT) and International Livestock Research Institute (ILRI) in collaboration with national partners (IITA, 1999).

A combination of improved varieties and improved cropping systems for higher productivity and profitability with a minimum use of insecticides and fertilizers have been developed for the dry savannas of West Africa (Ajeigbe, 2003; Ajeigbe et al., 2005; Singh et al., 2003, 2004). These cropping systems (two cereal: four cowpea row to row strip cropping system) involving improved varieties of crops, with selective use of fertilizer and pesticides, feeding of crop residues to small ruminants in permanent enclosures on the home compound and returning of the manure to the field, hold great promise for increasing the food production in West Africa without affecting the environment or degrading the soils. Small scale farmers prefer the improved intercropping system over monoculture because it provides them with sufficient cereals for home use and additional cowpea for cash income. Farmer participatory on-farm evaluation of improved cowpea varieties and improved cowpea-sorghum and cowpea-maize intercropping systems has led to rapid farmer to farmer diffusion and adoption of the new planting systems.

Large scale on-farm evaluation and validation of the system covering several states and over 1600 farmers for large scale adoption started in 2002. This paper presents some of the results of these field trials in the Sudan savanna zone of Nigeria.

MATERIALS AND METHODS

Locations, farmers selections, pre-season training and discussion

The study started in 2002, Kano State in north central Nigeria, extended to Jigawa State in 2003 and ended in 2005. Consultative meetings were held with stakeholders to select participating villages. Strategies for input (seed, insecticide and fertilizer) distribution were made. Volunteer farmers were selected and each participating farmer provided 0.4 to 1 ha of farmland for the improved system of cultivation. Criteria used included accessibility of the farmland, willingness of farmers to practice improved agronomic practices, payments of cost for inputs provided and to allow data collections. Training was provided to the farmer's representatives together with extension staff and other technicians. All field operations were carried out by farmers supervised by technicians, the extension agents and trained farmer's group leaders.

Input distribution and group training

Farmers receive input either in full credit or 50% credit. The inputs included seed, fertilizers and insecticide. Payments of credit were either in kind at harvest or in cash. During the input distributions, farmer groups received further training on agronomic activities that would be carried out during the course of the project implementation.

Crop varieties

Cowpea: Improved cowpea varieties were used which included IT90K-277-2, a dual purpose variety popular in the area. In locations where Striga infestation was high, IT97K-499-35 a Striga resistant variety was given to the farmers.

Cereals: Improved (ICSV111 and ICSV400) and local varieties (Farafara and Kaura) of sorghum were used. The local varieties were tall and long duration, adapted to low soil fertility and in high demand by farmers in areas where their stalk is used for fencing and fuel. As with sorghum, both improved (SOSAT C88) and local varieties (Ex-Borno) of millet were used, while open pollinated medium and extra early maize varieties of maize were used.

Improved cropping system and other agronomic practices

The system involved 2 rows of densely planted cereals (Millet, sorghum or maize) to 4 rows of densely planted cowpea. Sorghum and maize were planted at 25 cm within row, 3 and 5 seed of maize and sorghum respectively were sown per hole, thinned to 2 plants per hill 2 weeks after sowing (2 WAS); millet was planted at 50 - 100 cm within row, 6 - 10 seed were sown per hole thinned to 3 plants per hill 2 WAS, while cowpeas were planted at 20 cm within row, 3 seeds were sown per hole and thinned to 2 plants per hill 2 WAS. Thinning was done after good rains to minimize loss in soil moisture and drying of roots. Simultaneous planting of the cereals

and cowpea to reduce shading of cowpea by cereals was recommended and adopted. Planting was done only when there was sufficient moisture which was guaranteed if there was a rainfall of 20 mm and above. Some farmers also planted improved cowpea as sole crops for seed production in the second and third years.

Land preparation was done using deep ploughing, followed by harrow then ridging at 75 cm, Ox drawn ridger at 75 cm or ridging manually as the case may be. Fertilizer recommendation include 1 ton manure per ha on a yearly basis followed by application of 100 kg NPK (15:15:15)/ha as basal. The manure and fertilizer were applied after harrowing before ridging. The cereals especially maize were top dressed with urea at about the rate of 50 kg urea/ha. These were done at about 3 - 4 WAS. The method was spot application and the urea was covered with adequate soil to avoid evaporation and runoff. Putting about full bottle cover per hole dug about 10 cm from the base of the plant was sufficient.

Cowpeas were sprayed with insecticides 2 - 3 times before harvest. First spray to control aphids and thrips was at about 3 - 4 weeks after planting or at budding. The second spray to control thrips and maruca pod borer was 10 - 14 days after or at podding. The third insecticide spray was optional which was determined by the presence of maruca and pod sucking bug attack. The insecticides used were either cypermethrin or a formulated combination of cypermetrin and dimetheoate at the manufacturer recommended rate of 1 L/ha.

Two to three manual weeding starting from 3rd week after planting was recommended and adopted. The first weeding was 3 - 4 WAS, second weeding was done three weeks later after which the third weeding may be hand pulling of a few stands as the crops would have covered the ground well enough to prevent weed growth.

Harvesting was based on crop maturity and was done when over 90% of crop was matured and dry. After harvest, pods, cob or panicles were sun dried, threshed carefully and winnowed to separate the grains from the chaff. Grains were stored in cool dry places mostly using the triple bagging system.

Traditional cropping practices

In the Sudan savanna zone of Nigeria, crop production is based mainly on intercropping systems of varying complexity involving mainly sorghum, millet, maize, cowpea and groundnut. These crops occur in the fields in various mixtures and various combinations. The dominant crop mixtures however are 'millet-cowpea', 'sorghum-cowpea', 'millet-sorghum-cowpea', millet-cowpea-groundnut and sorghum-cowpea-groundnut (Henriet et al., 1996). Land clearing as well as ridging were generally done manually or with bullock-drawn implements. In some fields, ridging was not done and sowing was on the previous year's ridges.

The spacing between ridges varied from 75 to 100 cm. Many of the field received farm yard manure (FYM) and some amount of chemical fertilizer was applied as top dressing on the cereals 2 - 4 weeks after sowing. Henriet et al. (1996) quantified the FYM applied to average 4000 kg/ha (fresh wt). Planting and weeding were done manually with the aid of a hoe. Weeding was done twice or thrice depending on the weed situation and the availability of labour. Harvesting was done when the pods/panicle are dried. Cereals were sown first on alternate ridges approximately 1.5 to 2 m apart and 80 to 100 cm hill to hill either immediately after ridging or, depending upon the moisture level of soil. After the next rain, legumes were sown on the blank rows. The special arrangement and date of planting varied considerably from field to field and crop geometry became complex when all the four major crops (millet, sorghum, cowpea and groundnut) were planted in the same field.

Data collection

A baseline survey of the participating farmers was carried out by administering questioner farmers. A quadrat of 45 m^2 (10 m × 4.5 m) was fixed in each of the farmers fields and the produce from these quadrats were used for yield estimation. After harvest of the last crop, which in most cases was sorghum or late cowpea, the price of the grains in the local market were determined and used to calculate the economic value of the produce. Quadrats were also fixed in adjacent farmers' fields of traditional system of local varieties, traditional planting pattern and low input to serve as control. The mean productivities of the participating farmers as well as traditional controls were calculated. Percentage increase of improved system (% IIS) over the traditional system, was calculated by dividing the value of the improved system by specific traditional system and multiplied by 100. A frequency polygon was plotted for grain yields and number of farmers in 2003 to give indication of the distribution.

RESULTS

Background information of participating farmers

The general background information of participating farmers is shown in Table 1. The average family size was high ranging from 10 members in Jigawa State to 11 in Kano State. The farmers generally tend to have more than one plot with average total plot size ranging from 4.0 ha in Kano State to 6.3 ha in Jigawa State. Most of the farmers owned livestock especially small ruminants. Many farmers also owned work bulls especially in Jigawa State.

Farmers participation, grain/seed production

The number of participating farmers and estimated grain productions are given in Table 2. In 2002, 90 farmers participated in the trial in Kano State. A total of 642 farmers participated in both State in 2003, while 1168 farmers including 187 women farmers participated in 2004 and in 2005 a total of 1655 farmers including 297 women farmers participated. Based on the average yield and plot size, an estimated 27 tons of cowpea grain was produced in 2002 out of which about 80% was certified as seed, of which about 12 tons was purchased by the project for use in 2003. A total of 428.5 tons of improved grains of cowpea was produced in 2003 out of which an estimated 40% was certified as seed. A total of 17 tons of IT 90K 277-2 cowpea varieties were purchased from participating farmers for 2004 on-farm trials. In 2004, about 610.1 tons of improved grains were produced, while about 717.5 tons were produced in 2005 by the participating farmers. The number of farmers that directly participated in the evaluation in Jigawa State in 2005 was less than that of 2004 owing to limited resources and to accommodate for increase in Kano State. However, these farmers and several others planted the improved

Table 1. Range and mean of land and livestock holding of farmers involved in the farmer participatory evaluation of improved cropping system in the Sudan savanna of Nigeria.

Variables	Kano State		Jigawa State	
	Range	Mean	Range	Mean
Family size	1 - 60	11.2	2 - 25	9.5
No. of plots	0 – 15	3.6	0 – 20	7.7
Plot size (ha)	0 – 73.5	4.0	0 - 22	6.3
Number of livestock owned				
Sheep	0 - 30	5.6	0 - 50	7.4
Goat	0 - 40	6.7	0 - 26	5.3
Cattle	0 - 30	1.4	0 -19	1.2
Work bulls	0 – 4	0.5	0 - 6	0.9
Poultry	0 - 160	13.5	0 - 50	9.9

varieties and planting systems on their own.

Crop yields

Kano State

The mean grain and fodder yields of cowpea and cereals and the gross returns in each year are indicated in Table 3. In 2003, mean grain yield of cowpea was 1137 kg/ha and mean grain yield of sorghum was 688 kg/ha. This was from a purchased input of less than US $83. The mean value of the grains from the improved system was US $611 and the total produce (grain and fodder) was US $895, these compared favorably with the value of grains and total produce in the traditional systems which ranged from US $290 to US $373 and US $332 to US $560, respectively. The grain yields gave gross return of 164 to 211% of the traditional control while the total produce gave gross returns of 160 to 269% of the total produce of the traditional control. The different cowpea grain yields obtained by farmers followed a normal distribution curve; while the sorghum grain yields obtained was slightly skewed to the left (Figure 1).

In 2004, farmers had the choice of cereals to be planted with many of them opting for maize and improved millet. However, the cowpea grain yields were comparable to previous year and averaged 987 kg/ha in the strip cropping system and 1456 kg/ha in the sole cropping. The mean gross return from the grains of sole cowpea (US $607) was comparable with gross return from the grains of the improved strip cropping system (US $635). The grain yields gave a gross return of 254 to 569% of the traditional control while the total produce gave gross returns of 247 to 476% of the total produce of the traditional control. The productivity in 2005 follows similar pattern as 2003 and 2004. Even if the gross returns from only grains was considered, farmers made a mean of 288% of the traditional system in three years.

Jigawa State

In 2003 (Table 4), the mean grain yield was 807 kg of cowpea grain and 600 kg of cereal grain (totaling 1407 kg/ha) while mean stover yield was 1191 kg of cowpea fodder and 1561 kg of cereal stalk (totaling 2752 kg/ha). The mean gross income from the grains was US $456 while mean total gross income was US $631. When the grain productivity and gross value were compared with the mean obtained from traditional controls, the improved system produced 110 to 299% of the value of the grains of the traditional systems. In 2004, the improved system produced 190% of the grain value of the traditional systems, while 360 to 396% of the grain value of the traditional system was produced in 2005.

DISCUSSION

Several research results (Jones, 2000; Mulatu and Belete, 2001) noted that one of the causes for low adoption of technologies appeared to be research centre recommendations that may be irrelevant to the small farmer's priorities and resource constraints, as well as being inappropriate to the physical, cultural and economic environment. The result from this trial however, showed that the 2:4 cereals: cowpea cropping system was not only superior to the local practices but is also appropriate to the socio-cultural practices of the resource poor farmers. Inputs are limiting factors to increase agricultural productivity of the resource poor farmers in this region, the cash input required in this system was about US $83 per ha. With the provision of credit in kind for one crop season (about 4 months) farmers were able to pay back and also break the poverty cycle of low input-low output and subsequently gain profit for their investment which they reinvested on their farms. Several authors (Ali and Byerlee, 1991; Ghatak and Ingersent, 1984; Kalirajan and Shand, 2001) noted that the big yield gap between possibility and reality was mainly due to poor extension services, institutional and cultural constraints, and farmers` long adaptability to traditional practices.

The average yields recorded in this project were similar to the on-station yields recorded (Ajeigbe, 2003; Ajeigbe et al., 2006; Singh et al., 2003, 2004) in the region. This was due to the vigorous training of the farmers, extension agents, provision of inputs and the simplicity of the new technology. Extrapolating from the interviews and discussions with participating farmers, this study has been very successful in catalyzing large scale production

Table 2. Total number of farmers that directly participated on-farm participatory evaluation of improved cropping system in the Sudan savanna 2002 - 2005.

Year	Number of farmers			Number of village	Area (ha)	Cowpea grain produced (ton)
	Jigawa	Kano	Total			
2002	-	90	90	5	37	27.0
2003	61	581	642	28	360	428.5
2004	380	788	1168	49	593	610.1
2005	267	1388	1655	88	759	717.5

Table 3. Crop productivity (kg/ha) and the economic value (Naira/ha) of produce of farmers participating in the improved cropping system in Kano State, 2002 - 2005.

	Legumes		Cereals		Economic value (US $)		(%) Increase of improved system	
No. of farmers	Grain	Fodder	Grain	Fodder	Grain	Total		
			2002					
Mean of 40	731	2909	769	1731	625	1303		
			2003					
Mean of 367	1137	1942	688	2429	611	895		
			2004					
Mean of 279 **	1456	2051	-	-	607	948		
Mean of 418	987	1778	1073	4061	635	999		
			2005					
Mean of 523**	1388	1619	-	-	694	896		
Mean of 644	933	1938	1238	4139	776	1191		
Traditional systems			**2003**				**Grain**	**Total**
*G:Ml	413	1227	115	2017	373	560	164	160
C:G:Sg:Ml	519	1621	548	1002	290	510	211	176
C:Sg:Ml	397	1109	732	1541	315	480	194	187
Sg			1625	2205	330	366	186	244
Ml			1410	1598	306	332	200	269
			2004					
Sg:-C	148	557	901	3695	250	404	254	247
Mi:-C	93	374	350	2166	112	210	569	476
Ma:C	267	437	652	1533	247	346	257	289
			2005					
Sg:Ma:C	264	978	1251	4020	445	735	174	162
Mi:Ma:C	170	756	911	1933	313	488	248	244
Sg:C	204	415	546	2366	239	389	325	306
Mi:C	126	271	204	1454	114	208	680	571

*C= Cowpea; G= Groundnut; Ma= maize; Sg= sorghum; Mi= millet, **Sole cowpea cropping; Conversion US $1= ₦ 100.

Table 4. Crop productivity (kg/ha) and the economic value (Naira/ha) of produce of farmers participating in the improved cropping system in Jigawa State, 2003 - 2005.

No of farmers	Legume		Cereal	Economic value (US $)		Increase of improved system (%)		
	Grain	Fodder	Grain	Fodder	Grains	Total		
				2003				
Mean of 61	807	1191	600	1561	456	631		
				2004				
Mean of 204	884	1601	873	2494	544	852		
				2005				
Mean of 226	902	1170	893	2310	674	917		
Traditional systems				**2003**			**Grains**	**Total**
C:Sg:Ml	311	932	1376	6415	417	657	110	96
Sg:Ml:G	266	1354	908	5839	266	532	172	119
Sg:C	111	1110	533	2975	153	341	299	185
				2004				
Sg:C	311	2210	754	2934	287	704	190	121
Mi:C	369	2026	640	3044	287	675	190	126
				2005				
Sg:C	155	558	438	838	187	292	360	314
Mi:C	197	614	287	1016	170	289	396	317

*C= cowpea; Ma= maize; Sg= sorghum; Mi= millet.

of improved seeds of new cowpea varieties. Assuming an average rate of adoption of 10 secondary farmers from each participating contact farmer, the new technology has already been adopted in full or in part by over 16550 farmers in the two states.

The new system comprising of improved grain type and dual-purpose cowpea varieties along with high yielding cereal crops in an improved cropping pattern have shown 3 fold increase in productivity and gross income compared to the traditional 1 row cereal: 1 row legume intercropping. The improved systems recommended only about 38 kg N per ha and therefore where farmers diverted fertilizer to other crops the cereal yields were compromised. Farmers who were unable to procure fertilizers opted for monoculture of cowpea and the study encouraged them by providing manures for their fields. The productivities of these farmers increased and with a lower investment they were generating an income similar to farmers practicing improved strip cropping systems.

Also, farmers with larger fields started cultivating improved varieties of cowpea in monocultures especially for sale as seeds, after receiving trainings seed production techniques. It has been noted (Ajeigbe, 2003; Ajeigbe et al., 2006) that monoculture of cowpea in rotation with cereals was most profitable under optimum management practices but they, (Ajeigbe, 2003; Ajeigbe et al., 2006) recommended the 2:4 strip cropping system as suitable to the socio-economic situations of farmers in the Sudan savanna zone of west Africa where inputs are limiting. This was also stated by Hildebrand (1976) who noted that intercrop is common where farmers lack land and/or capital, but labour was plentiful. The average farm families of participating farmers were large, indicating that labour was plentiful. In this trial, it was noticed that, as the ability of the farmers to generate income increases they tend towards monoculture. The improved strip cropping system therefore bridges the gap between sole cropping and the traditional intercropping systems. It is therefore a good developmental tool to alleviate poverty of farmers. Another interesting development noticed was the development of Farmers Cooperative Associations by participating farmers which was encouraged and facilitated by the projects. These groups are now involved in sourcing inputs and loans for farmers from several sources including self help and members' contributions.

Conclusion

The adoption of improved cowpea-cereal cropping

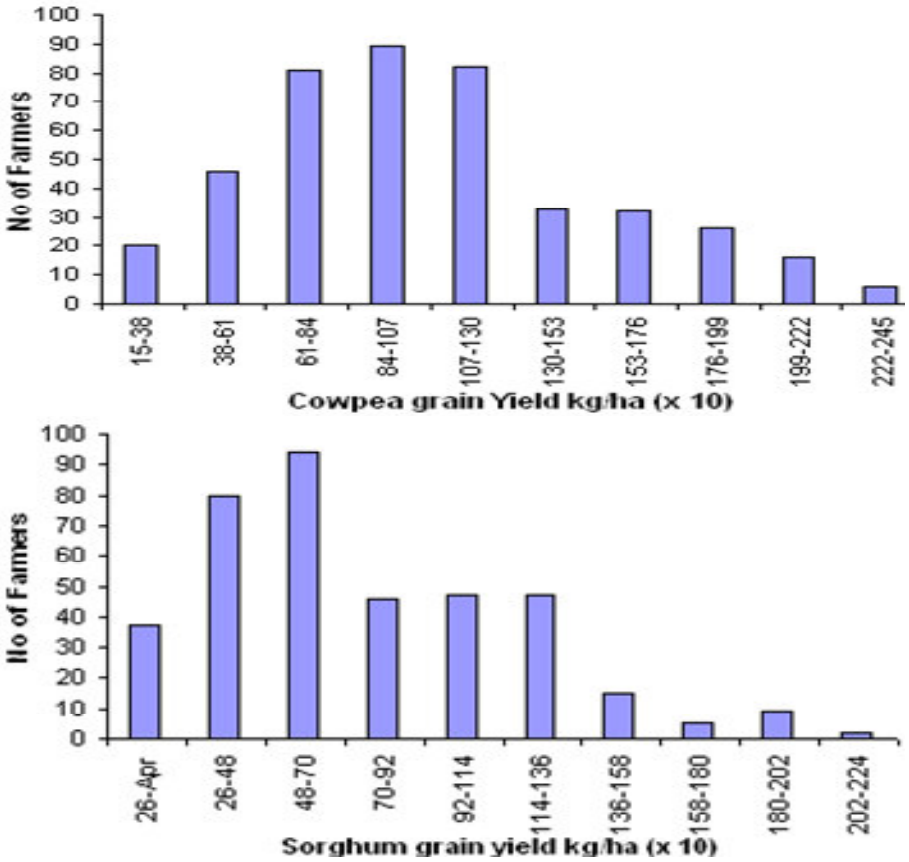

Figure 1. Frequency of component grain yield by participating farmers in Kano State, 2003.

systems and improved varieties of crops coupled with trainings of farmers and extension agents has been shown to be a key to increasing the productivity and income generations of resource poor farmers of the Sudan savanna of Nigeria in a sustainable manner. The study has clearly shown that adequate technologies and fair access to inputs and skill development through training is very important in transferring the fortune of the resource poor farmers who are the major producers of food in Sub-Saharan Africa. Major lessons learnt from this trial are that appropriate technology needs not be a drastic change from farmers practice and involving farmers early in technology development and testing aids its adoption. Owing to the success of the project, the Gatsby Charitable Foundation is funding a second phase of the project which is charged with wider dissemination of the improved systems as well as crop varieties and extending the activities to Sahel savanna zone of Niger Republic.

ACKNOWLEDGEMENTS

The authors are grateful to the Gatsby Charitable Foundation, United Kingdom. for funding this work through the IITA/Gatsby Project No. 2252 titled `Improved crop-livestock system for enhanced food security and poverty alleviation in West Africa`.

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