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Participatory on-farm evaluation of improved legume-cereals cropping systems for crop-livestock farmers: Maize-double cowpea in Northern Guinea Savanna Zone of Nigeria

H. A. Ajeigbe[1]*, B. B. Singh[2], J. O. Adeosun[3] and I. E. Ezeaku[1]

[1]International Institute of Tropical Agriculture (IITA), Kano Station, P. M. B. 3112, Kano, Nigeria.
[2]Department of Soil and Crop Sciences R.M. 428 Heep Building Texas A&M University College Station, Texas 77843, USA.
[3]National Agricultural Extension, Research and Liason Services, Ahmadu Bello University, Zaria, Nigeria.

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Farmer's participatory evaluation of improved cowpea-maize cropping systems in the Northern Guinea Savanna of Nigeria involving over 1000 farmers was conducted from 2003 to 2005. The system involved growing improved cowpea varieties with maize in a 2 cereal: 4 cowpea row to row (arrangement), with application of inorganic and organic fertilizer to the crops and 2 to 3 insecticide sprays to cowpea. The result indicated that the improved cropping systems using improved varieties of cowpeas were superior to the traditional system. The economic value of grain of the improved system averaged 313, 269 and 308% of the traditional systems in 2003, 2004 and 2005 respectively. The improved systems also produced better quality crop residues with increase in the leguminous portion of the residues and therefore improve productivity of the livestock. Farmers' cooperatives societies were vital in procurement of inputs, accessing bank loans and loan recoveries and in subsequent farmer to farmer diffusion of both improved varieties and cropping systems. Participatory on-farm evaluation of improved cowpea varieties and improved cowpea-sorghum and cowpea-maize intercrop systems has led to rapid farmer to farmer diffusion and adoption of the new technologies.

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

INTRODUCTION

Cowpea [*Vigna unguiculata* (L.) Walp.], is grown throughout West Africa from wet to dry zones in a variety of crop mixtures, but the importance of cowpea as a component crop is greater towards the northern areas where rainfall is less and soils are poor (Mortimore et al., 1997). Though, Africa grows the largest hectrage at 8.9 of the 9.1 million ha worldwide (FAOSTAT, 2007), cultivation is mainly under traditional systems and it therefore has the lowest average yield. In a general survey of cropping systems in West and Central Africa conducted from 1988 to 1990 covering: Nigeria, Benin Republic, Niger Republic, Togo, Cameroon, and Burkina Faso, Singh (1993) identified 15 major cropping systems, in addition to several others which vary from farmer to farmer.

The traditional inter-cropping system involves little or no application of fertilizers and chemicals. Such practices lead to decreasing soil organic matter contents, increasing populations of chronic parasitic weeds (eg. *Striga* spp.), reduced soil biological diversity and enhanced erosion risk (Mortimore et al., 1997; Singh and Ajeigbe, 2002). Due to the increasing population in the region and resulting reduction in arable land per capita, there is a need to increase yields per unit area. Improving

*Corresponding author. E-mail: h.ajeigbe@cgiar.org.

Table 1. Range and mean of land and livestock holding of farmers in Northern Guinea savanna zone of Nigeria.

Variables	Range	Mean
Family size	2 - 26	9.9
No. of plots	1 - 10	3.6
Plot size (ha)	0.25 - 30	2.3
Number of livestock		
Sheep	0 - 10	2.8
Goat	0 - 13	3.3
Cattle	1 - 25	0.8
Work bulls	0 - 4	0.8
Poultry	0 - 40	11.9

cowpea yields under these intercropping systems, and minimizing the biotic and abiotic constraints in such a way as to increase cowpea yield without reducing cereal yields is the challenge of agricultural scientists. Thus, the challenge is to maximize the benefits of small amount of purchased inputs like fertilizer and chemicals and use of manure from the existing livestock to enhance organic matter in the soil and increase and sustain crop productivity. On-station trials by International Institute of Tropical Agriculture (IITA) in Kano, Samaru and Bauchi, in northern Nigeria (Ajeigbe, 2003; Singh et al., 2004) have shown that overall farm yield could be increased in a sustainable manner through adoption of improved varieties and 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 selective use of insecticides and fertilizers have been developed for the moist and dry savannas of West Africa (Ajeigbe, 2003; Ajeigbe et al., 2006; Singh et al., 2003, 2004). These improved varieties and cropping systems (2 cereal: 4 cowpea row to row strip cropping system) 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 holds great promise for increasing the food production in West Africa without affecting the environment or degrading the soils. This system in the Northern Guinea savanna zones encourages intensification by double cropping the cowpeas within the season and also judicious use of inorganic fertilizer and manure. A farmer participatory on-farm validation and dissemination of the improved cowpea-cereal intercrop systems in the Northern Guinea Savanna zone of Nigeria, was started in 2002, to speed up the adoption of the improved system and cowpea varieties, and to improve the productivities of the small scale farmers in the region. This paper presents some of the results of these trials from the Northern Guinea savanna zone of Nigeria.

MATERIALS AND METHODS

Locations, farmer's selections and pre-season training of farmers

The study that started in Kaduna State; in North Central Nigeria in 2002, was extended to the Federal Capital Territory (FCT) in 2003, covering the core Guinea Savanna zone of Nigeria. Consultative meetings were held between the National Agricultural Research Institutes (Institute of Agricultural Research Samaru, and Nigeria Agricultural Extension Research and Liason Services both of Ahmadu Bello University Zaria) the Kaduna State's and Federal Capital Territory (FCT) Agricultural Development Programs (ADPs) and 8 (Giwa, Igabi, Soba, Ikara, Zaria and Chikun Kaduna State and Gwagwalada and Gwale in FCT) participating Local Government Councils (LGCs) to recommend the initial participating villages.

Pre-season meetings/trainings were held in major villages (Giwa, Yakawada, Turunku, Miagana, Ikara, Kaujuru, Gwagwalada, Tuga Maje and Gwale) to discuss the project aims and objectives. These meetings were held with the farmers, the ADPs and LGC officials, traditional rulers and scientists from the NARIs. Strategies for input (seed, insecticide and fertilizer) distribution were developed. Volunteer farmers (Table 2) were selected and each participating farmer was required to provide 0.4 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 of inputs provided and allow of data collections. All field operations were carried out by farmers, supervised by the extension agents and trained farmer's group leaders. The farmers were organized into groups of 10 to 20 members, each with an elected group leader. The ultimate aim was for the groups to graduate to register farmers associations. The farmer's representatives together with extension staff were invited to research stations and ADP offices (Samaru, Miagana and Kaduna) for further trainings.

Table 2. Total number of farmers that participated in the trials.

Years	Number of farmers			Number of villages	Area cultivated (ha)	Cowpea grain produced (tons)
	Kaduna	FCT	Total			
2002	60	-	60	5	24	40.6
2003	277	20	297	15	174	351.6
2004	487	200	687	35	295	493.5
2005	737	500	1237	83	456	779.6

Input distribution and group training

In the first year (2002), all the farmers received inputs on credit for three months. The inputs were distributed to the farmers at the village level. They were each given between 10 kg seeds of improved cowpea varieties (IT93K-452-1 and IT89KD-288), enough to plant 0.4 ha. Each farmer was given the two cowpea varieties, IT93K-452-1 to be planted early for cowpea grain production and IT89KD-288 to be planted after the harvest of the early planted cowpea for cowpea grain and fodder production. Other inputs received included insecticides (1 - 2 L of Cypermetrin+dimethoate EC 30 g + 250 g ai), fertilizers (50 - 100 kg of NPK 15:15:15 and 50 kg of urea) and maize seed (3 – 6 kg). Payments at harvest for fertilizer and insecticides were either in cash or in kind using seed while payment of seed was with seed. In subsequent years (2003 - 2005) second year farmers were required to pay 50% of the cost of fertilizer and insecticides at the time of distribution or upfront, while new farmers received inputs on credit for three months. By the third year all farmers were required to pay for the cost of fertilizer and insecticide upfront. During the distributions, which were on group basis, each group received adequate training on agronomic activities that would be carried out during the course of the project implementation. Scientists and extension agents (from IITA, IAR, NAERLS, NSS, Kaduna State and FCT ADP) visited farmers' fields for inspections and further training on specific operations, during the cropping season. The training included how to plant the improved cropping system (spacing and planting geometry), fertilizer applications, safe use of insecticide etc. Special training on cowpea seed production practices were given to selected farmers in all location to encourage village level seed production of improved cowpea varieties. The Nigeria National Seed Service (NSS) was contacted to certify the farmer's fields, while seeds were purchased from farmers based on recommendations by NSS for subsequent distributions to other farmers. Farmer's field days and field walk were held at different locations during which farmers and general public had opportunities to see the fields and had discussions with researchers and policy makers.

Crop variety

Cowpea: Improved varieties of cowpea were used. IT93K-452-1 (60 day cowpea) was planted simultaneously with maize, while IT89KD-288 was planted as a relay crop.
Cereals: Maize: Medium to long duration maize varieties including hybrids were recommended.

Agronomic practices of the improved cropping system

Land preparation

A deep ploughing followed by double or single harrow, then ridge at 75 cm was generally recommended and used wherever available. Ox drawn ridgers at 75 cm were also used or ridging manually as the case may be. The farmers were allowed to choose from the options available to them and depending on available resources.

Planting pattern and spacing

The improved system involved 2 rows of densely planted maize to 4 rows of densely planted double cowpea. Close plantings were recommended for both maize and cowpea. Cowpeas were planted at 20 cm within ridge, 3 seeds per hole and thinned to 2 plants per hill 2 weeks after sowing (2 WAS). Maize was planted at 25 cm within ridge 3 seed per hole, and thinned to 2 plants per hill (2 WAS). Thinning was carried out after good rains. Simultaneous planting of the cereals and cowpea was recommended to reduce shading of cowpea by maize. Planting was conducted only when there was sufficient moisture which was guaranteed by a rainfall of about 20 mm and above at maximum of 24 h before planting.

The first cowpeas were planted same day as the maize in May/June when the rains have been established and were harvested 60 days later in August. The residues left after the first cowpeas were either used as fodder for large ruminants or left on the field as mulch. The second cowpeas were planted on the rows in between the hills of the first cowpea and on the maize rows. Maize is harvested by the end of September leaving the second cowpea which is harvested in October/November. In the FCT where land holdings were smaller and rain fall was longer, farmers planted cowpea as relay with early planted maize or double crop cowpeas in a sole cropping system using the above spacing.

Fertilizer applications

Organic and inorganic fertilizers were used in the improved system. Manure at the rate of 1 ton per ha on a yearly basis were applied as recommended for this system. This was followed by application of 100 kg NPK (15:15:15)/ha as basal. The NPK provide 15 kg N, 15 kg P2O5 and 15 kg KCl per ha. The manure was extremely variable ranging from high quality mainly cow and sheep dropping to mixture of dropping, liters, left over food etc. The manure and NPK fertilizer were applied after harrowing just before ridging. The maize was top dressed with urea at 50 kg urea/ha. The 50 kg urea per ha will provide 23 kg N per ha but this was applied only on the 2 maize rows which is equivalent to 0.33 of the area and there the maize receives 76 kg N when top dressed with urea in this planting arrangement. These were carried out at 3 - 4 weeks after sowing (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. No manure or fertilizer was applied to the second cowpeas.

Table 3. Productivity of the best and overall means of farmers participating in the improved cropping system in the Northern Guinea Savanna Zone of Nigeria, 2003.

Farmers	IT93K-452-1		Maize		IT89KD-288		Value in Naira	
	Grain	Fodder	Grain	Stalk	Grain	Fodder	Grain	Total
Aliyu Saidu Rinji	1057	1132	1922	1998	2178	971	207878	243419
Amadu Mohammed	1133	799	3577	2332	1203	1288	202648	238617
Alh. Ahmed Rufai	888	910	2044	2087	1733	1647	180106	222635
Mean (231 Farmers)	777	1214	1333	1711	943	892	120658	155670

	Legumes		Cereals		Value in Naira		% value increase by I.C.S.**	
Traditional systems*	Grain	Fodder	Grain	Fodder	Grains	Total	Grains	Total
C:Ma:Sg	710	365	1280	2439	66245	76597	182	203
C:Sg	488	422	1554	2020	61716	72083	196	216
Ma:Sg			1465	2233	35165	39631	343	393
C:Mi	300	326	300	1221	22777	30114	530	517
Mean							313	332

Cash Input / ha = 3 bags of fertilizer (N6100), 3 L of cypermethrin N1650 Total = N7750. *C = cowpea, Ma = maize, Sg = sorghum, Mi = millet, S = soybean; **I.C.S. = Improved cropping system; US$ 1 = N 100.

Insecticide spraying

The cowpea plants needed insecticide spray 2 - 3 times before harvest. First spray was at about 3 - 4 weeks after planting or at budding. The next spray was 10 - 14 days after or at podding. The third insecticide spray which was usually optional was necessary if there was pod sucking bug (PSB) attack. The first spray was to control aphids and thrips; second spray was to control thrips and maruca pod borer while the third spray was to control maruca and PSB.

The insecticides recommended were cypermethrin, or combination of cypermethrin and dimethoate. These formulations are fairly popular with farmers and are available in the markets under various brand names. One litre of the chemical was recommended to spray 1 ha of sole cowpea crop per spray. In the improved strip cropping system 700 ml was enough per ha because cowpea occupies only 66% of the cropped area.

Weeding, harvesting and storage

The fields were manually weeded to keep the field weed free. The first weeding was at 3 WAS and the second weeding was carried out three weeks later, after which the extra-early maturing cowpeas are harvested two weeks later. The land is then ridge up for planting of the second cowpea on both the old cowpea ridges and between the maize stands on the maize ridges. After harvesting the extra-early cowpeas, some farmers spray the field with paraquat (a non selective contact herbicide) to kill the weeds and cowpea. They thereafter planted the second cowpea and the dead weeds and cowpea therefore served as mulch. The herbicide had limited damage on the companion maize. The second cowpea was normally weeded once at 4 WAS. Harvesting was based on crop maturity. Harvesting was conducted when over 90% of crop was matured and dry. After harvest, pods/cobs were sun dried, threshed carefully winnowed to separate the grains from the chaff. Grains were stored in cool dry places mostly using the triple bagging system.

Traditional cropping system

The dominant grain crops in the Northern Guinea savanna zone of Nigeria are maize, sorghum, millet, cowpea, soybean and groundnut. The farmers intercropped cowpea with maize, sorghum, soybean, groundnut and other food crops. Land clearing as well as ridging were generally conducted manually or with bullock-drawn implements.

The spacing between ridges varied from 75 - 120 cm depending on the method of land preparations. Many of the fields received farm yard manure (FYM) and some amount of inorganic fertilizer as well as topdressing of maize fields 2 - 4 WAS. Planting was carried out manually with the aid of a hoe.

In the maize-sorghum-cowpea system the maize and sorghum are planted early and cowpea is relayed with the maize. The system varies from alternate rows of maize and sorghum to alternate hills of maize and sorghum or two rows of maize to one row of sorghum or vice versa depending on the farmers' food preference and market demand.

Soybean or groundnut may replace any of the cereals or cowpea. Within ridge spacing for cereals ranged from 25 - 100 cm, and 40 - 100 cm for cowpea. Groundnut and soybean were generally planted closely at about 20 cm within ridge.

Weeding was done manually with the aid of a short-handled hoe and sometimes with a bullock-drawn ridger or cultivator. Weeding was conducted twice or thrice depending on the weed situation and the availability of labour. Harvesting was carried out when the pods/panicle are dried.

Background information of participating farmers

General background information of participating farmers is given in Table 1. The average family size was high (10) ranging from 2 to 26 members. The farmers generally tend to have more than one plot (mean of 4) with mean total plot size of 2.3 ha. Most of the farmers owned livestock especially small ruminants. Many farmers also owned work bulls with a mean of 1 work bull per family.

Table 4. Productivity of the best and overall means of farmers participating in the improved cropping system in the Northern Guinea Savanna zone of Nigeria, 2004.

Name	IT93K-452-1		Maize		IT89KD-288		Economic value	
	Grain	Fodder	Grain	Fodder	Grain	Fodder	Grains	Total
Haruna Liman	1800	3000	2533	4444	2278	2222	267196	380518
Abi Umar	2266	2280	978	1155	2222	1978	248864	336322
Alh. Haruna Musa	1000	967	2000	1905	1811	5555	190537	324779
Mean (324 farmers)	820	1318	1612	2139	923	1084	113589	160588
SE	20	31	34	52	24	44	1953	2670

	Legumes		Cereals		Value in Naira		% value increase by I.C.S.**	
Traditional systems*	Grain	Fodder	Grain	Fodder	Grains	Total	Grains	Total
Sg:C:S	733	853	778	1778	56106	76726	202	209
Ma:Sg:C	406	317	1177	4207	49717	64464	228	249
Sg:S	526	603	678	2378	43265	60087	263	267
Ma:C	541	733	544	1038	40644	57386	279	280
Ma:S			1611	3837	40274	51206	282	314
Sg:C	389	400	489	3000	31664	45662	359	352
Mean							269	278

Cash Input / ha = 3 bags of fertilizer (N7500), 3 L of Cypermethrin N1800, Total = N9300. *C = cowpea, Ma = maize, Sg = sorghum, Mi = millet, S = soybean; **I.C.S. = improved cropping system.

Farmer's selections, input distribution and recovery and trainings of farmers

In 2002, 60 farmers in Kaduna State participated in the trial (Table 2). A total of 297 farmers from Kaduna State and Federal capital territory were covered in 2003, while 687 farmers including 117 women farmers were selected in 2004 and in 2005, 1237 farmers including 306 women farmers participated. The inputs given to farmers depended on the size of plot allocated to the trial and a minimum of 0.4 ha to maximum of 1 ha. The maximum cost was less than ten thousand naira per ha (US$ 100). After selling their produce almost all the farmers were very happy to pay back the cost of inputs.

Cost of inputs recovery which was facilitated by the farmer's group leaders was over 95%. Voluntary advance payments by farmers and groups were encouraging and in the third and fourth years, only the new farmers were given credit for three months, all other farmers paid full cost of input including handling charges in advance.

Data collection and analysis

A baseline survey of the participating farmers was carried out by the project with the aim of gathering socio-economic data for future impact assessment studies. A questioner was administered on each farmer before participation. A quadrat of 45 m^2 (10 m × 4.5 m) was fixed in each of the farmers field and the produce from these quadrats were used for yield estimation. After harvest of the second 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 during the season to serve as controls.

The mean grain yield, standard deviation and standard error were calculated. Standard error (SE) was given by the following formula:

$SE = \text{Std dev}/\sqrt{n}$

Where Std dev = Standard deviation
$\sqrt{n}$ = square root of n
N is number of farmers

Percentage (%) of value increase of the improved cropping system over the traditional systems was calculated using the following formula:

%value increase = (mean value of improved system/value of traditional system) × 100

During the farmer's field days and farmers field walks the participants including other invited farmers were asked simple questions about the technologies including the cowpea varieties. The number of other farmers that were exposed to the technology through farmer to farmer diffusion was also determined. The project staff also carried out a number of surveys to determine the level of adoption in the pilot villages.

RESULTS

Grain/seed production of improved varieties

The distributions of participating farmers and estimated grain productions are given in Table 2. Based on the average yield and plot size, an estimated 60.6 tons of cowpea grain was produced in 2002 out of which about 60% was certified as seed of which about 5 tons was

Table 5. Productivity of the best and overall means of farmers participating in the improved cropping system in the Northern Guinea Savanna Zone of Nigeria, 2005.

Name	IT93K-452-1		Maize		IT89KD-288		Economic value	
	Grain	Fodder	Grain	Fodder	Grain	Fodder	Grains	Total
Abdullahi Haruna	910	4884	3774	5994	1465	1754	255744	385281
Ado Abdulahi	2331	1998	2509	4440	1310	1954	293706	375180
Sagir Abdu	1554	4440	2220	3552	1443	1820	246420	358086
Mean (505 farmers)	899	2585	1203	2297	1098	1486	142023	209987
SE	11.95	49.51	23.23	75.04	12.07	18.5	2090.8	3071.2

	Legumes		Cereals		Value in Naira		% value increase by I.C.S.**	
Traditional systems*	Grain	Fodder	Grain	Fodder	Grains	Total	Grains	Total
Ma:C	529	963	745	1317	54100	75130	263	279
Ma:Sg:C	383	525	725	1254	44733	58886	317	357
S:Sg	707	1369	338	461	41431	54943	343	382
Mean							308	339

Cash Input / ha = 3 bags of fertilizer (N7500), 3 L of cypermetrin N1950 Total = N9450. *C = cowpea, Ma = maize, Sg = sorghum, Mi = millet, S = soybean; **I.C.S. = Improved cropping system.

purchased by the project for use in 2003. A total of 351.6 tons of improved grains of cowpea was produced in 2003 out of which an estimated 40% was certified by NSS and could therefore be used as seed. A total of 13 tons of IT93K-452-1, 17 tons of IT90K-277-2 and 10 tons of IT89KD-288 cowpea varieties were purchased from participating farmers for 2004 on-farm trials. In 2004, about 493.5 tons of improved grains were produced, while about 779.6 tons were produced in 2005 by the participating farmers. In each of the year the project purchased certified seeds for the following season and farmers sold the remaining seed through farmer to farmer diffusion of seeds.

Cropping system

As a result of combined supervision by IITA, collaborating Research institutes, ADPs, LGA and farmer's leader's effort, the farmers had excellent plant establishments in all locations in all in the 3 years. Occasional but minor mistakes were noticed in the planting arrangements, where a few farmers planted 1 cereal: 4 cowpea or 2 cereals: 5 cowpea. Some farmers diverted some of the fertilizer meant for the trial to other crops especially lowland rice and sole maize.

Each farmer cultivated between 0.4 and 1 ha of the improved system. The average yield from the farmer's field and the best three farmers in 2003 is given in Table 3. The best three farmers had a mean grain yield of 5245 kg ha^{-1} including 2731 kg of cowpea grain and giving a grain value of over N 190000. The productivities of the best 3 farmers showed the potential productivities of the improved system. The mean grain yield of 231 farmers was of 3053 kg ha^{-1} comprising 1750 kg of cowpea and 1333 kg of maize. Mean total economic value of produce N 155670 comprising grain valued at N 120658. This was with a cash investment input of about N 7,750. The system gives an average of over 300% of the different traditional systems. Among the traditional systems, the highest grain (N 66245) and total value (N 76597) was obtained from the cowpea–maize-sorghum system. Similar results were obtained in 2004, Table 4 and 2005, Table 5. In 2004, (Table 4) the mean productivity of the improved system was 209 to 352% value of the traditional system with average of 278%. This was from a cash investment of N 9300. The cash investment in 2005 was N 9450 and the mean productivity of the improved system was 279 to 382% value of the traditional system with average of 339%.

The improved system also produced higher quantities of crop residues especially the legume (cowpea) residues than the traditional systems (Tables 3, 4 and 5). The purchased input includes 100 kg of NPK 15, 15, 15, 50 kg of urea and 3 L of insecticide. After paying for the purchased inputs, farmers were left with profit that can be further invested in their farms. This is assuming that the farmers would use their household labour. Even with hired labour which is likely to be equal for both improved and traditional systems, the improved system was highly profitable compared to the traditional practice.

Technology diffusion

Results showed that from every participating farmer in

project, about 10 - 15 other farmers purchased seeds or collected it free and adopted the new technology in full or in part on their own after observing the technology in the previous year. Some of the villages like Yakawada and Kaya in Kaduna State were almost fully saturated with the new cowpea varieties. In addition, the extra-early cowpea variety is being adopted by farmers who are using it as niche crop in several cropping systems including relay with rice and sugarcane in the lowland valleys.

DISCUSSION

The result from this trial has shown that the 2 cereal: 4 cowpea cropping system is not only superior to the local practices but also appropriate to the socio-cultural practices of the resource poor farmers. Input is a limiting factor to increase agricultural productivity of the resource poor farmers in sub-Saharan Africa (SSA). However, too much inputs especially inorganic fertilizer and pesticide are not desirable because of the obvious environmental concern. The improved system recommended in this trial applied 1 ton manure, 100 kg NPK 15:15:15 ha^{-1} as basal application and 50 kg of urea ha^{-1} to top dress the cereals. It also requires maximum of 3 insecticide sprays on the cowpea to protect it from insect pests. Thus, it involves selective application and judicious use of these inputs. One-third cereal to two of legumes minimizes the need for fertilizer while the applications of manure help in the provision of micronutrient and improve the inorganic fertilizer use. The average on-farm yields recorded in this trial was similar to those recorded on-station by Ajeigbe (2003), Singh et al. (2003, 2004) and Ajeigbe et al. (2006). This was due to the vigorous training of the farmers, extension agents, and provision of inputs and simplicity of the new technology. Extrapolating from the interviews and discussions with participating farmers, this project has been very successful in catalyzing large scale production 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 123,000 farmers in several states. The farmer to farmer diffusion of seed and other technology is very important given the poor formal seed production and dissemination system in Nigeria and the concentration of the private seed sector on maize and other cereals. The dissemination of new improved cowpea varieties through farmer to farmer diffusion has been noted to be effective in Northern Nigeria (Singh et al., 1997; Iniazumi et al., 1999; Kormawa et al., 2004). However Alene and Manyong (2006) noted yield variations among the various levels of farmers due mainly to differential adoption of improved packages. They therefore recommended the promotion of package adoption in the farmer to farmer dissemination processes.

The new system comprising improved grain type and dual-purpose cowpea varieties and high yielding cereal crops in an improved cropping pattern have shown up to 300% superiority in productivity and gross income compared to the traditional cereal-legume intercropping systems. In the Northern Guinea savanna zone of Nigeria the maize-double cowpea system produced on average 1500 kg cereal grain ha^{-1} with 2 ton stalk and 2 ton cowpea grain ha^{-1} with 2 ton fodder. The first cowpea which was normally harvested 60 days after planting provided food, green manure/green forage and cash in the lean period (mid rainy season), while the second cowpea and maize provided food, fodder and cash. Some farmers paid all of their debt from the sales of the first cowpea. The second cowpea was planted immediately after harvest of the first cowpea in all of the rows including maize rows. The maize was later harvested and the second cowpea was left on the field to be harvested about a month later.

The total food from the system in Northern Guinea savanna zone was higher than Sudan savanna zone because of the extended rainfalls and the advantage of the availability of extra early maturing cowpea variety that can also be harvested in the middle of the rains. This allow for the double cropping of cowpea and production of extra cowpea for food, cash and fodder for livestock. The improved systems recommended only about 38 kg N ha^{-1} in split dose; however the second fertilizer (urea) application is only on the cereal rows (0.33). The second application of fertilizer (23 kg N ha^{-1}) on only the cereal rows equals applying approximately 70 kg N ha^{-1} and therefore the maize had sufficient N. This coupled with the rotations of cowpea with maize in subsequent years and application of manure generated in the homestead makes the system sustainable and ensure that the yield of the cereal was not compromised. It can also be expected that intensified cereal/ legume intercrop would not only fix more nitrogen, but also leave more residual N than left by the traditional system. Most farmers had more than one farmland with some of them opting for sole cropping of cowpea with application of manure especially when inorganic fertilizer was limiting. These plots were then rotated with sole cereals in subsequent years. Ajeigbe (2003) and Ajeigbe et al. (2006) noted that sole cropping was most profitable under optimum management practices but recommend the 2:4 strip cropping system where input especially fertilizer is limiting. The average farm families of participating farmers were high indicating that labour may be plentiful since all able bodied members participate in farm activities. In this trial, it was noticed that, as the ability of the farmers to generate income increases they also tend towards sole cropping. The improved strip cropping system therefore bridges the gap between sole cropping and the traditional intercropping systems and is therefore a good

developmental tool to alleviate poverty of farmers.

The system therefore has the potential for changing the traditional farming system into a dynamic and sustainable commercial agricultural endeavor.

The traditional intercropping system produces more cereal residues and less leguminous fodder because the legumes population as well as yields were low due to competition for light, they therefore produce less biomass, while the new system produces high amount of nutritious cowpea fodder**.** This adds to the nutritive value of total crop residues and improves the livestock nutrition especially in the dry season. Thus, the strip-cropping system involving 2 rows of cereals: 4 rows of cowpea not only produces higher grain yields but also sufficient quantities of cereals and cowpea residues that can be fed to livestock and increase crop-livestock integration. Singh et al. (2003), reported that in a controlled sheep feeding experiments, sheep fed cowpea haulms as a supplement to a basal diet of sorghum stover have shown higher live weight gain compared to those on sorghum stover *ad libitum*. The combined increase in productivity of crop and livestock encourage the farmers to invest in livestock pen constructions which help in generating higher amount of manure for soil fertility improvement.

Several authors (Jones, 2000; Mulatu and Belete, 2001), have identified the cause of low adoption of technologies to be the fact that research centre recommendations may be irrelevant to the small farmers priorities and resource constraints, as well as being inappropriate to the physical, cultural and economic environment. However the result from this trial has shown that the 2:4 cereals: cowpea cropping system is not only superior to the local practices but also appropriate to the socio-cultural practices of the resource poor farmers. Input is a limiting factor to increase agricultural productivity of the resource poor farmers in this region, the cash input required in this system was about N10, 000 ha^{-1} (about US$ 78). 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 with profit from their investment they were able to invest more on their farms. The formations of Farmers Cooperative Societies by participating farmers was encouraged and facilitated by the projects. The cooperative societies formed are now helping farmers with access to loans from commercial banks as well as government agencies with a high degree of success. They are also helping in sourcing for input by linking farmers to agro-input dealers as well as marketers.

Conclusions

The improved cowpea–cereal cropping system with selective application of inputs shows superiority of up to 200% over the traditional cropping system in the Northern Guinea savanna zone of Nigeria. The trial has shown in clear term that the productivity of resource poor farmers in the Guinea Savanna zone of Nigeria can be sustainably increased through adoption of improved cropping systems and improved varieties of crops, coupled with skill development through trainings of farmers and extension agents. Appropriate technology should allow flexibility in its adoption and needs not be a drastic change from farmers practice. The provision of affordable inputs and within reach of farmer is however as important as the improved technologies.

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