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Research Article

Using a Participatory Approach and Legume Integration to Increase the Productivity of Early Maturing Maize in the Nigerian Sudan Savannas

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Drought, infestation of cereal crops by the parasitic weed *Striga hermonthica*, and poor soil fertility are the major constraints to maize production by smallholder farmers in the Sudan savannas of northern Nigeria. Four innovation platforms (IPs) were therefore established in 2008 in the Sudan savanna (SS) agroecological zone of northern Nigeria to create a stakeholder forum to address these identified food production challenges in the target areas. The IPs comprised researchers from Bayero University, Kano; Institute for Agricultural Research, Zaria; International Institute of Tropical Agriculture; state and local government extension programs in Kano and Katsina states; input and output dealers; community-based organisations; and media organisations in the two states. The current study reports on the effects of legume integration on maize performance in farmer fields and the adoption of *Striga* management technologies introduced in the IPs over a four-year period. The deployment of drought-*Striga*-tolerant and early-maturing maize varieties along with legume rotation reduced *Striga* infestation by 46–100% when cowpea was rotated with maize, 80–97% when groundnut was rotated with maize, and 59–94% when soybean was rotated with maize. Grain yield of maize increased by 63–88% when cowpea was rotated with maize, 69–128% when groundnut was rotated with maize, and 9–133% when soybean was rotated with maize. Participatory and detailed questionnaire-based adoption surveys showed high adoption of improved maize varieties, five years after program interventions. The maize variety 99EVDT-W-STR C0 was the most popular among all the IPs because it is early maturing, *Striga*-resistant, and drought-tolerant. The high maize yields and high adoption rates suggest that the IP approach was effective in disseminating maize technologies.

1. Introduction

Maize is gradually replacing the traditional cereal crops such as *Sorghum* (*Sorghum bicolor* (L) Moench) and pearl millet (*Pennisetum glaucum*) in the dry savannas of West and Central Africa [1]. Although maize is primarily cultivated in the Guinea savannas in northern Nigeria where the length of growing season and rainfall are sufficient to support maize production, maize production is also gradually spreading to the drier Sudan savanna (SS), where the length of growing season is short because of the availability of early maturing and high yielding varieties [2]. Maize production in the SS of West Africa is limited by short growing season, intermittent drought, infestation by the parasitic weed *Striga hermonthica*, and poor soil fertility [3, 4]. These constraints may occur together in the SS, leading to a yield reduction of 80–100% [5]. To address these constraints, researchers at both national and international research institutes have developed a number of technologies for dissemination among smallholder farmers. These include varieties that are resistant to both drought and *Striga* [3, 5] and cereal-legume rotation to control *Striga* and improve soil fertility [5–7]. The legumes cause suicidal germination of *Striga* and fix nitrogen which is made available to succeeding maize. Kamara et al. [5] and Franke et al. [7] reported a significant reduction in *Striga* infestation and increase in maize grain yield when *Striga*-resistant maize was grown in rotation with grain legumes in the Nigeria savanna. Despite the availability of technologies to address the effects of drought, poor soil fertility, and *Striga* infestation, their use is still very minimal in the SS of Nigeria leading to very low productivity of maize in these zones [8]. This may be attributed to the extension methods used in the promotion. Research technology transfer and technology use have been treated as independent activities. Research knowledge consisting of large prescriptive technology packages flows linearly from researchers to farmers through extension agents [9]. In a baseline study carried out in 2008 in the SS of northern Nigeria, Ayanwale [8] reported that access to and use of the extension service was generally low in all the study areas. Consequently, adoption of maize productivity enhancing technology was very low. For example, average adoption of improved maize varieties was 30% with wide variation among local government areas [8].

The International Institute of Tropical Agriculture (IITA) and its partners in recent years have developed new early maturing maize varieties because of the short growing periods prevalent in these areas and the incidence of drought, especially in view of rapid climatic variability. The early maturing maize varieties were disseminated to farmers using innovation platforms (IPs) under the premise of Integrated Agricultural Research for Development (IAR4D) adopted by sub-Saharan Africa Challenge Programme (SSA-CP). The SSA-CP proposed an alternative approach to address underperformance of SSA agriculture due to the traditional agricultural and research development (ARD) approach, which is characterised by organisation of research and development as a linear process [10]. The fundamental structure for this is an "innovation platform" (IP) comprising partners with diverse backgrounds who interact to support sustainable agricultural development. Innovation platforms are considered to be promising vehicles for increasing the impact of agricultural research for development (AR4D) [11, 12]. For example, the IITA-led Humid Tropics program successfully organised multistakeholder innovation platforms to demonstrate agricultural technologies in Burundi, Rwanda, and Democratic Republic of Congo [13]. In Burkina Faso, Teno and Cadilhon [14] reported that IPs contributed to increase their members' human and social capacity; improved exchange of information and knowledge between different stakeholders; and facilitated the access to agricultural support services. All these improvements led to increased crops and animal production among the project beneficiaries. Using IPs in the maize and cassava value chains, the project "dissemination of new agricultural technologies in Africa (DONATA)" significantly increased yields and incomes in maize and cassava and enhanced interactor relationships and behavioural change among the diverse social and economic operators [11].

The sub-Saharan Africa Challenge Programme (SSA-CP) which was initiated in 2004 had proposed an alternative approach that aims to appropriately put agricultural research within a larger system of innovation whereby knowledge from numerous sources (comprising all various actors and stakeholders) is integrated and effectively put into use. The SSA-CP operates a Pilot Learning Site (Kano-Katsina-Maradi PLS) referred to as KKM-PLS within the West African subregion. The Sudan savanna (SS) is one of the taskforces operating within the KKM-PLS with the aims to improve the productivity of farming systems and ensure efficient use of resources through technical, administrative marketing, and management improvements [9]. Activities in the SS subproject were launched by the IITA in collaboration with Kano State Agricultural and Rural Development Authority (KNARDA) and Katsina State Agricultural and Rural Development Authority (KTARDA) in February 2008. Working with partners in four local government areas (LGAs), Bunkure and Shanono in Kano state and Musawa and Safana in Katsina state, the project promoted improved agricultural technologies including improved maize production technologies. This was done within the IP launched at local government levels in Kano and Katsina states. Within the project, maize production technologies were disseminated to a large number of farmers in the platforms, using a participatory research and extension approach (PREA) [15].

The main objective of this paper is to illustrate how maize productivity was increased in the IPs using the appropriate technologies such as improved varieties, legume-maize rotation, and a participatory approach. Specifically, the study examined the following:

(1) The performance of an integrated maize production package that included the combined use of drought/*Striga*-tolerant maize varieties in rotation with grain legumes (cowpea, groundnut, and soybean) on farmers' fields in the Sudan savanna of Nigeria with respect to maize yield, *Striga* infestation, and *Striga* damage

(2) The adoption of recommended technologies among farmers in order to assess the potential to scale-up technologies through farmer-to-farmer extension

2. Materials and Methods

2.1. Site Description and Setting Up of Innovation Platform (IP). Innovation platforms were set up in 2 local government areas each in Kano and Katsina states. The local government areas lie in the Sudan savannas of Nigeria. The Sudan savanna zone extends between latitudes $9°30'$ and $12°31'$N and longitudes $4°$ and $14°30'$E and occupies about 12 million ha^{-1}. The zone has rainfall ranging between 500 and 800 mm per annum with a growing period of about 100 to 120 days [16]. The process for IP establishment started with the identification of multidisciplinary teams to implement project activities for specific crops. This brought a wider group of stakeholders together for training, agreeing partner roles, and budgets detailed in interinstitutional MoUs. Early in 2008, IP areas and commodity focuses were finalised and the first year's field activities commenced in 20 communities and later covered 40 communities over the 3-year period. The International Institute of Tropical Agriculture, the Centre for Dryland Agriculture, Bayero University, Kano (CDA), and the Institute for Agricultural Research in Zaria (IAR) were identified to support field research activities, while KNARDA, KTARDA, and the agriculture departments in the participating LGAs in the two states provided extension services in order to create awareness and strengthen capacity of farmers to adopt the use of improved agricultural technologies. Policymakers at the state and local government level provided support for subsidized inputs for farmers and capacity building and mobility of extension agents.

2.1.1. The Use of the Participatory Research and Extension Approach. The participatory research and extension approach (PREA) used involved a four-stage process. These were community analysis and mobilisation, action planning, implementation through field experimentation, and sharing of experiences [16, 17]. The project was implemented in 40 communities across four LGAs in the two states over the three-year period. During the 2008 community analysis, problems were identified and prioritised by each IP, and an action plan was agreed and implemented. This involved the strengthening of existing and creation of new community-based organisations (CBOs) or farmer groups through capacity building and training, resulting in farmer testing of new technologies aimed at addressing the identified problems, linking famers to input and output markets, and ensuring seeds of new crop varieties were readily available in local communities. This involved the establishment of community-based seed production, based on individuals selected by farmer groups, who were provided with the resources for certified seed production and sale within their communities. During 2008 and 2009, mid- and end-of-season participatory evaluations were undertaken, and plans for the next season were agreed. This process was coordinated by KNARDA and KTARDA in conjunction with each LGA IP, with support from researchers from IAR and CDA. Maize was confirmed as one of the major cereals grown in the targeted areas. Other crops that were identified to be important were rice, *Sorghum*, cowpeas, groundnuts, and soybeans, based on the predominant cropping system and prioritised problems in each community. *Striga* together with poor soil fertility were identified as the major biophysical constraints for maize production in all the identified communities. As a result of community mobilisation exercise, 200 lead farmers were selected from 88 CBOs to test maize production technologies. In order to make seeds of improved maize available to farmers, 48 maize seed producers were selected to produce and sell seeds at community level. Community seed producers were also identified to produce and make available seeds of improved legume varieties and to enhance legume integration for soil improvement and *Striga* management.

2.1.2. Field Experimentation. As a result of community mobilization, 200 lead farmers tested the *Striga* control methods during a two-season period over 2009 and 2010. Considerable emphasis was placed on encouraging legume-cereal rotations as part of a strategy for *Striga* control and improvement of soil fertility. The lead farmers tested the rotations of newly developed early-maturing and *Striga* and drought-tolerant varieties of maize with legume trap crops. The legume trap crops (cowpea, groundnut, and soybean) stimulate the germination of *Striga* seeds in the soil without allowing the *Striga* plants to parasitize their roots thereby leading to the death of the *Striga* plant. Training was provided for the extension agents (EAs) so that they in turn provided training for farmers not only in crop and *Striga* management but also in leadership and communication skills. This would enable the farmers to effectively lead their groups and disseminate *Striga* control and other maize production technologies. The lead farmers were encouraged to share with other members of their groups the skills and knowledge they had acquired during training and field evaluation activities. They were also encouraged to provide knowledge on *Striga* and soil fertility management to other farmers in their communities and to lead participation in evaluating the performance of the *Striga* control methods.

There were two treatments: an improved crop management plot (ICM) and farmer practice (FP) plot. The ICM treatment consisted of a legume crop in the first year followed in the second year by an improved maize variety selected from one of four varieties, based on farmer's choice. In addition, the same maize varieties were also grown as a sole crop alongside the legume crop in the first year to assess their effect on *Striga* control in comparison with local maize. For the legumes, the farmers selected cowpea, groundnut, or soybean based on their choice to grow in rotation with the maize. Maize varieties selected were either all early or extraearly maturing, which made it possible for them to fit into the short growing season in the Sudan savannas of Nigeria. The varieties were 2000SYN-EE-W-STR, 99EVDT-STR-W, 2004TZE-W-DT-STR-C4, 99TZEE-Y-STR, and FC. All the improved varieties were tolerant or resistant to *Striga* parasitism. FP comprised a local maize variety in both years. Most local maize varieties were retained seeds of improved varieties that had been acquired many years previously through the state extension agency or from the open market.

Farmers with the help of EAs laid out the plots of $20 \times 20\ \mathrm{m}^2$. Farmers were advised to grow all crops on ridges 0.75 m apart and plant maize with an intrarow spacing of 0.50 m apart. Two seeds of maize were planted per plant stand to give a plant population of 53,333 plants ha^{-1}. Soybean seeds were drilled at an intrarow distance of 0.05 m; groundnut was planted at 0.20 m distance using one seed per stand while cowpea was planted at a distance of 0.20 m apart using two seeds per plant stand. Farmers were provided with fertilizer to apply on all the plots. For the ICM plot, NPK 15 : 15 : 15 was applied one week after planting (WAP) at the rate of 50 kg N, 50 kg P_2O_5, and 50 kg K_2O ha^{-1} using standardised measures. Urea was used for top dressing maize plants with 50 kg N ha^{-1} at 4-5 weeks after planting (WAP) to give a total of 100 kg N ha^{-1}. The legume plots were supplied with single superphosphate (SSP) at 40 kg P_2O_5 ha^{-1} at planting. In the FP, lead farmers were asked to apply their own management practices. Fertilizer was provided to apply on the local maize if the farmers wished to do so. Farmers were also asked to bury the fertilizer in the ICM plots to minimise nutrient loss through rainwater run-off and volatilisation. In the FP, lead farmers were asked to apply the management practices as they see fit such as plant population, weeding, and fertilizer application. Many farmers also buried the fertilizer applied in the FP plots, especially in the second year. They, however, applied less fertilizer on their own plots because they considered the recommended fertilizer rates to be too high.

2.2. Data Collection and Analysis. Extension agents (EAs) collected data on farmers' field through an observation sheet. Data on *Striga* count in the maize plot were collected at 10 WAP. In each plot, four 1 m × 1 m quadrants were laid along two intersecting diagonal transects. Two quadrants were pegged out on one diagonal while the remaining two were pegged out on the other diagonal. In each quadrant, emerged *Striga* plants were counted. Grain yield was determined at physiological maturity at 10 WAP according to Kamara et al. [5]. At maturity, farmers with support from EAs harvested all the maize in a plot, dehusked, shelled, and weighed it. Representative samples of 20 cobs were shelled, and the moisture content was determined using a Dickey-John moisture meter. The moisture content was used to adjust yield to 12% moisture content. Soybean was harvested by cutting plants at ground level and air-dried before threshing. The moisture content of the grain was used to calculate grain yield per ha after adjusting to 12% moisture content. Cowpea pods were picked and air-dried before threshing and weighed to calculate grain yield after adjusting to 12% moisture content. Groundnut was pulled from the ground when fully matured and dried, and pod yield was taken after weighing.

Statistical analyses were performed on data collected in the maize plots in year 2 using SAS Statistical Software version 9.1 [18]. Prior to analysis, all plots in sites free of *Striga* were removed from the data set. *Striga* count was square root transformed before analysis of variance to improve normality. Variability of means is presented as standard errors between means (s.e.d.) with differences between means considered significant at the level of $p < 0.05$ using LSD.

2.2.1. Assessment of Adoption of Improved Maize Production Technologies. Participatory assessment (PASS) was undertaken towards the end of the cropping season in 2010 in 20 communities across 4 LGAs (Bunkure and Shanono in Kano state; Musawa and Safana in Katsina state) where maize was promoted in the cereal-legume-livestock IPs established. Participatory assessment involved discussions with groups of men and women firstly in undertaking a "Participatory Crop Varietal Evaluation" of the new maize varieties tested and grown by farmers. Secondly, the extent to which participating farmers had adopted the new maize varieties and management practices were estimated. It was recognised that adoption rates based on participating farmer discussions would be high. There was therefore a need for a formal survey to assess the adoption of the improved maize varieties introduced in two of the target LGAs. Participatory varietal evaluations were undertaken by separate groups of men and women. In each group, we confirmed existing and new varieties of each crop grown or tested. Secondly, we identified those criteria considered important in variety comparison, and thirdly, we scored each criterion for each variety on a scale of 1–3, one being poorest performing and three being the best performing. In addition, pairwise ranking was undertaken to directly compare and score the different crop varieties. The most important preharvest production criteria were the ability to provide high yields, early maturing, providing large grain, and being *Striga* and drought tolerant or resistant. The most important post-harvest criteria were the ability to provide good tasting food and a high market value for the grain or the processed crop.

Two separate household surveys were undertaken, one each in Bunkure LGA, Kano state and Safana LGA, Katsina state to ascertain the level of adoption of the improved maize varieties introduced in the two LGAs from 2008 to 2011. The surveys were undertaken in April 2013. A multistage sampling technique was used to select respondents for the study. In the first stage, the two LGAs where the IPs were established were purposively selected. The stratified random sampling technique was used to select respondents in each LGA. Data were collected with a structured questionnaire designed to capture information on 300 households across 10 villages in Safana LGA where less maize is produced and 200 households across 5 villages in Bunkure LGA where more farmers produce maize. The pretested questionnaire was administered between March and April 2013. Household data were collected on farm and farmer characteristics, as well as awareness and adoption rates of improved crop technologies. Data collected were analysed using SPSS. Data were analysed according to [19] using descriptive statistics. Frequency counts, percentages, and mean computations were used to describe the variables in the study.

3. Results and Discussion

3.1. Field Experimentation. Legume rotation generally reduced *Striga* infestation and increased maize grain yield (Tables 1–3). Mean *Striga* densities were higher in the farmers' choice of continuous maize plots (FC) than those in plots where maize was rotated with any of the legumes (Tables 1–3). The cultivation of *Striga*-susceptible maize greatly increased *Striga* infestation. When grown in rotation with cowpea, *Striga* population was reduced by 46–100% with a corresponding maize grain yield increases ranging from 63 to 88% (Table 1). Rotation with groundnut reduced *Striga* population by 80–97% and increased grain yield by 69–128% (Table 2). Similarly, rotation with soybean reduced *Striga* infestation by 59–94% with a corresponding yield increase ranging from 9 to 133% (Table 3). The extent of reduction appears to be similar among the legume varieties. Franke et al. [7] reported high reductions in *Striga* seed bank

Table 1: *Striga* count ha^{-1} and mean grain yield of different maize varieties following cowpea on farmers' field in Sudan savannah.

Year 1 (2009)	Year 2 (2010)	*N*	*Striga* ha^{-1}	% reduction	Grain yield ha^{-1}	% increase
Cowpea	2000SYN-EE-W-STR	8	0	100	3177	70
Cowpea	2004TZE-W-DT-STR-C4	8	17515	46	3510	88
Cowpea	99TZEE-Y-STR	8	5515	83	2864	53
Cowpea	99EVDT-W-STR	10	1667	95	3046	63
FC	FC	32	32192		1871	
Mean			**11378**		**2894**	
SED			8538		391	

Table 2: *Striga* count ha^{-1} and mean grain yield of different maize varieties following groundnut on farmers' field in Sudan savannah.

Year 1 (2009)	Year 2 (2010)	*N*	*Striga* ha^{-1}	% reduction	Grain yield ha^{-1}	% increase
Groundnut	2000SYN-EE-W-STR	8	6566	80	3014	96
Groundnut	2004TZE-W-DT-STR-C4	8	4007	88	2593	69
Groundnut	99-TZEE-Y-STR	8	5566	83	3149	105
Groundnut	99EVDT-W-STR	10	6833	79	3493	128
FC	FC	32	32182		1534	
Mean			**11031**		**2757**	
SED			7511		478	

Table 3: *Striga* count ha^{-1} and mean grain yield of different maize varieties following soybean on farmers' field in Sudan savannah.

Year 1 (2009)	Year 2 (2010)	*N*	*Striga* ha^{-1}	% reduction	Grain yield ha^{-1}	% increase
Soybean	2000SYN-EE-W-STR	8	3112	85	3375	96
Soybean	2004TZE-W-DT-STR-C4	10	8415	59	2891	68
Soybean	99TZEE-Y-STR	8	1313	94	1875	9
Soybean	99EVDT-W-STR	10	3022	85	4022	133
FC	FC	32	20357		1724	
Mean			**7244**		**2777**	
SED			4934		620	

in groundnut-maize (46%) and soybean-maize (50%) rotations. Ellis-Jones et al. [14] reported that maize grown after soybean (1.44 t·ha^{-1}) produced grain yield that was significantly higher than that grown after local maize (0.73 t·ha^{-1}) and *Sorghum* (0.95 t·ha^{-1}). In comparison, maize grown after cowpea produced an average yield of 1.32 t·ha^{-1}. Maize grown after a previous legume trap crop produced an average yield of 1.38 t·ha^{-1} but only 0.84 t·ha^{-1} when grown after a previous cereal crop. They also reported that the grain yields (1.32 t·ha^{-1}) of *Striga*-resistant maize were significantly higher ($p < 0.005$) than those of local maize. The mean yields of the local maize (0.90 t·ha^{-1}) were 47% less than those of the *Striga*-resistant maize. They attributed the increase in maize yields to a reduction in *Striga* infestation in maize fields following legumes or on *Striga*-resistant maize. Kamara et al. [5] reported a 39% increase in grain yield of *Striga*-resistant maize grown after soybean. The reduction in *Striga* infestation of maize grown in rotation with legumes confirms the importance of growing legumes in the first year to reduce *Striga*, even when *Striga*-tolerant or -resistant maize varieties are grown.

3.1.1. Assessment of Adoption of Improved Maize Production Technologies. Maize varieties were ranked using pairwise ranking techniques (Table 4). Results show that 99EVDT-W-STR was considered the best maize variety, although 99TZEE-Y STR was also ranked highly in some communities. Kamara et al. [20] used the same approach to assess farmer adoption of improved cowpea varieties in northeast Nigeria. They confirmed that farmers preferred improved varieties because of high yields.

Table 4: Maize variety ranking using pairwise ranking (1 = highest).

Variety	Bunkure	Shanono	Musawa	Safana
Local	4	4	5	4
99EVDT-W-STR	1	1	1	1
2000SYN-EE-STR-W	3	—	4	2
2004TZE-W-DT-STR-C4	4	3	2	3
99TZEE-Y-STR	1	2	3	1

After the maize varietal rankings, participants were asked to indicate who had tried or planted one of the new varieties and used the new management practices. A positive response was taken as a measure of adoption on at least part of his/her farm. Overall results (Table 5) indicate that 39% of the participants had adopted improved maize varieties. Rates of adoption did however vary between LGAs, with the highest rates of adoption being in Bunkure. Bunkure LGA is situated largely within or near the very big Hadejia-Jamaare irrigation scheme, where farmers have more access to market than other LGAs. When participants in Bunkure and Shanono were asked which varieties they intended to plant, the next growing season, many chose to plant the improved

Table 5: Adoption of new maize varieties and management practices reported by farmers.

LGA	Number in groups	Adoption of new varieties of maize (%)	Legume-cereal rotation (%)	High plant population (%)	Fertilizer application (%)	Burying fertilizer (%)
Bunkure	115	56	92	76	93	79
Shanono	82	48	42	62	61	49
Musawa	143	30	14	16	30	18
Safana	250	20	83	95	95	56
Average	**148**	**39**	**58**	**62**	**70**	**51**

maize varieties (Table 6). Eighty-one percent of the participants indicated their intention to plant 99EVDT-W-STR because of tolerance to both drought and *Striga*, while 47% intended to plant 99TZEE-Y-STR because of its short duration in the field. The results reported in this paper are consistent with those of Ellis-Jones et al. [14], which showed that the IP approach using PREA is likely to enhance technology adoption. The adoption of many of the new management practices was consistently high across communities (Table 5). For fertilizer application, this was 70%, increasing plant populations (62%), and legume-cereal rotations that included mixed and relay cropping of cereals and legumes (58%). Fifty-one percent of participants reported burying of the fertilizer at application. However, as reported by Kamara et al. [5], complaints about the additional labour and the tediousness of the work required for burying the fertilizer and high costs of fertilizer application may limit the area of land over which they are applied. As with adoption of new varieties, adoption of new management practices was highest in Bunkure and Safana and consistently less in Musawa (Table 5).

Survey results established that most of the households were male-headed (93% in Bunkure and 88% in Safana). Most of those interviewed belonged to an existing group (69% in Bunkure and 63% in Safana). Seventy-nine percent of the farmers in Bunkure had access to extension agents while 77% had access in Safana. Eighty-nine percent of the respondents in Bunkure were aware of the improved maize varieties and 91% having awareness in Safana LGA. The high percentage of awareness compared to 34.5% in Bunkure and 36% in Safana in the baseline undertaken in 2008 [10] shows that the project was effective in dissemination of information about the improved maize varieties. It also shows that the extension agents and the use of PREA were very effective in providing information about improved maize varieties in the two LGAs. Kudi et al. [21] also reported high level of awareness of improved maize varieties in Kwara state, Nigeria, leading to high adoption of maize varieties. About 69% of the respondents had adopted improved maize varieties in Bunkure LGA (Table 7). In Safana LGA, 45% of the respondents had adopted the improved maize varieties. Results show that the adoption of the variety 99EVDT-W-STR was highest among the varieties across the two LGAs. Adoption of this variety was 61% in Bunkure and 29% in Safana in 2012. The variety 2009EVDT-W-STR was also adopted by 10% of the farmers in Safana LGA. Adoption of the other varieties was very low.

Table 6: Percentage of participants indicating which variety they intend to plant next season.

Crop and variety	Bunkure (%)	Shanono (%)	Both areas[1] (%)
Local maize	9	0	4
99EVDT-W-STR	74	87	81
99TZEE-Y-STR	46	47	47
2000SYN-EE-W-STR	31	—	16
2004TZE-W-DT-STR-C4	25	18	22

[1]This question was not asked in Musawa and Safana.

Table 7: Adoption of improved maize varieties in Bunkure and Safana LGAs, 2012.

Varieties	Bunkure (%)[1]	Safana (%)[1]
99EVDT-W-STR	60.6	28.70
2009EVDT-W-STR	4.4	10.00
99TZEE-Y-STR	2.5	1.33
2000SYN-EE-W-STR	1.9	5.00
ACR95-TZE-COMP5-W	0.0	0.67
Total	**69.4**	**45.70**

[1]Percentage of farmers indicating that they were growing new varieties.

The varieties 99EVDT-W-STR and 2009EVDT-W-STR are both tolerant to drought and resistant to the parasitic weed *Striga hermonthica* in addition to being early in maturity. The variety 99EVDT-W-STR, which was released in Nigeria in 2009 as SAMMAZ 27, was widely promoted among farmers in the study area. Several seed companies and community seed producers were provided with seeds of this variety for production and marketing in the study area. Although 2009EVDT-W-STR is also tolerant to drought and resistant to *Striga*, it has not been released in Nigeria and was therefore only tested in farmers' fields for the purpose of release by the national seed council. Although the other varieties were tolerant to *Striga* and early maturing, they were not tolerant to drought. Farmers indicated drought tolerance, *Striga* resistance, early maturing, and high yield as reasons for adopting improved maize. The two varieties that possessed these qualities were therefore highly preferred by the farmers. Our results clearly showed that the project succeeded in promoting the improved maize varieties in the two LGAs as confirmed by the report of the baseline study carried out in 2008 and reported by Ayanwale et al. [8] who showed a baseline adoption of 38% of the improved maize varieties prior to the interventions by the SS taskforce. The increasing adoption of the early maturing varieties in the two

LGAs contrasts the situation where no innovation platform was set up as reported by Yanguba [22] who found only 13.3% adoption of early maturing varieties in Katsina state. He attributed the low adoption to lack of seed and fertilizer in the absence of any innovation system approach to ensure availability of those inputs to farmers. To increase adoption of the promoted maize varieties, the Sudan savanna taskforce provided training for both extension agents and farmers and link farmers to seed producers and government-subsidized fertilizer. Mbavai [23] and Kamara [24] cited lack of seed as the major reason why farmers did not adopt improved cowpea and soybean varieties, respectively, in northern Nigeria.

4. Conclusions

The innovation system approach used to address problems of food production in the Sudan Savannas of Nigeria involved multistakeholders in identifying maize production constraints and providing solutions to increase maize productivity. The deployment of drought- and *Striga*-tolerant and early-maturing maize varieties along with legume rotation reduced *Striga* infestation by 46–100% and increased maize grain yield by 9–133% depending on the legume crop used in the rotation. Adoption surveys showed 45–69% adoption of improved maize technologies four years after program interventions. The maize variety 99EVDT-STR-W was the most popular variety among farm households across the LGAs that constituted the IPs. This is due to its drought-tolerant and the parasitic weed *Striga* resistance characteristics. It is also preferred because it is early maturing and high yielding. The results of this study show that there is a clear benefit in the use of the *Striga* management technologies in northern Nigeria. A detailed study is needed to determine the impact of the use of these technologies on *Striga* infestation of maize fields, productivity, food security, income, and poverty in the project areas.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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