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Original Research Article

Effects of Preceding Cowpea on the Performance of Maize in Cowpea-Maize Sequential Cropping

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Abstract

Field experiment was conducted at the Federal University of Agriculture in 2004/2005, 2005/2006 and 2006/2007 cropping seasons to investigate the effects of cowpea varieties on succeeding of maize crop. The experiment was laid out in split-plot design and the treatment replicated three times. The main plot treatment was sprayed and unsprayed cowpea (*Vigna unguculata* L.) while variety constituted the subplot treatment (IT90K-76, IT90K-277-2, *Drum*, *Olo*, *Oloyin*, *Mallam* and *Sokoto* varieties). Maize variety cv TZESR-W was planted as the test crop in the early cropping season of 2005, 2006 and 2007 on each subplot of the preceding cowpea. The biomass of cowpea in the spray plots were higher than those of unsprayed at 8, 10 WAP in 2004. *Olo* variety had significantly lower biomass compared to others in 2004. The grain yield of cowpea from the sprayed plots was significantly higher than the unsprayed plots in all the years. IT90K-76 variety had the highest grain yield whereas *Mallam* and *Drum* had the lowest in all the years. Maize grain yields from the preceding cowpea plots were significantly higher than that of 0 N kg/ha. The fertilizer equivalent of the preceding varieties of cowpea ranges between 24 and 38 N kg/ha. Thus, preceding cowpea enhances the performance of succeeding maize.

Key words: Grain cowpea, insecticidal spray, maize, fertilizer replacement value, preceding crop

INTRODUCTION

Decline in soil fertility is a major problem contributing to the low maize grain yield in tropical and subtropical regions where many soils lack adequate plant nutrients and organic matter (Gulleridge and Shelton, 1994). Farmers address the problem by using various options such as the application of organic and inorganic fertilizers. Leaching of applied N-fertilizer is a source of potential hazard to the environment and underground water. It has been postulated that nitrous oxide (N_2O) contributes to catalytic destruction of ozone in the stratosphere (Crutzen, 1981). These problems have led to renewed interest in the use green manuring and leguminous cover crop to improve soil productivity. The major constraints to the use of green manuring and cover crops are that there are costs involved in establishing the legume, management, incorporation of green manure and the practice is not appealing because they do not yield food or cash directly to offset the cost of investment (Roger, 1995; Adigbo and Momoh, 2007).

Integration of grain legume crops into the existing cropping system has been reported to offer the potential for overcoming these problems. In addition to its role as a source of protein in the diet, N from legume fixation is essentially "free" N for use by the host plant or by associated or subsequent crops. Replacing it with fertilizer N would cost $7 to 10 billion annually, whereas even modest use of alfalfa in rotation with corn could save farmers $200 to 300 million (Peterson and Russelle, 1991). The movement of potash from the legume root zone to the root zone of non-legume crops providing a source of K has also been documented (Allison, 1990).

Thus much work has been done on the effect of preceding legumes on the succeeding cereal (Carsky et al., 2000; Carsky et al., 2004)). However, there is dearth of information on the use of the same inter and intra spacing for both preceding and the succeeding crops. Furthermore, there is dearth of information on the performance of maize plant succeeding sprayed cowpea plant with the associated high grain yield compared to unsprayed cowpea plant which is associated with severe insect infestation coupled with little or no grain yield. Therefore the objectives of the study are to (1) investigate the effects of preceding sprayed and unsprayed cowpea on the performance of the succeeding maize (2) select the best cowpea variety that will not only contribute soil N to the succeeding maize but also produce high harvestable grain yield and (3) to estimate the fertilizer equivalent value of the preceding cowpea on the maize grain yield. It is pertinent to mention here that this paper is not a duplicate of Adigbo and Adigbo (2011) published in Archives of Agronomy and Soil Science which focuses on the comparative performance of seven varieties of cowpea grown in two ecologies [upland ecology during late wet cropping season and wetland (inland valley) during the dry season but on residual moisture].

MATERIALS AND METHODS

The field experiment was conducted in 3 years (2004/2005, 2005/2006 and 2006/2007 cropping seasons) at the University of Agriculture. Using procedures described by Burt (2004), the top 1- 20 cm soil layer had pH (1:2 soil: water) of 6.54, 6.85 mg kg^{-1} K measured using Flame photometry 1.10g kg^{-1} organic matter (Walkley-Black method), 0.054 g kg^{-1} total N (Macro-Kjeldahl method) and 4.39 mg kg^{-1} Bray extractable P. The soil textural class was loamy soil (840 g/kg sand, 108 g/kg silt and 52 g/kg clay).

The available long-term climatic data are: precipitation (1148 mm/annum) and mean temperature (28 °C). Abeokuta has bimodal rainfall. The first peak of the bimodal rainfall lies between April and early August while the second peak of the rainfall is between mid to late August and October/ November depending on the season. The off season lies between November and March.

The experiment was laid out in split-plot design. The main plot treatment was insecticidal spray (sprayed and unsprayed) whereas cowpea variety constituted the subplot treatment. Seven varieties of cowpea used were IT90K-76, IT90K-277-2 (improved varieties), *Drum*, *Olo*, *Oloyin*, *Mallam* and *Sokoto* varieties (local). The plot size was 5.6 m × 3 m and the spacing was 80 cm × 20 cm for both crops.

Three seeds/hole of cowpea varieties were planted on the flat on the 2nd September 2004, 31st August 2005 and 5th September 2006 and were thinned down to 2 plants/stand 2 weeks after planting (WAP). In the early season of 2005, 2006 and 2007 early maturing maize TZESR-W was planted using the same intra- and inter spacing as the test crop on each subplot of the preceding cowpea plots (cowpea-maize sequence). Four other plots treated with inorganic fertilizer (i.e. 0, 30, 60 and 90 kg N ha^{-1}) were introduced in the early seasons at 3 WAP of 2005, 2006 and 2007 as the control treatments as well as to determine the N-fertilizer equivalent of the seven preceding cowpea varieties. These plots treated with fertilizer were also planted to maize in late season to remove residues of the applied fertilizer in the early season (i.e. maize-maize sequence).

Phosphorus deficiency symptom was generally observed in the early season maize. Hence, 30 kg P_2O_5 ha^{-1} was applied to all plots of maize according to Adetunji's (1994) recommendation. Adetunji (1994) noted that annual application of 30 kg P_2O_5 ha^{-1} could keep available P above critical level and maintained maize and cowpea yields at near maximum.

Weeding was done at 3 and 8 WAP for both crops. The spraying of cowpea was done at 6, 8 and 10 WAP for cowpea grown during 2004 because of extended rains while those of 2005 and 2006 were sprayed at 6 and 8 WAP.

The data generated from maize were subjected to analysis of variance (ANOVA) using split plot. Furthermore, maize grain yield obtained from early season maize of maize-maize sequence (0, 30, 60 and 90 kg N ha^{-1}) plots as well as those of pooled means from sprayed and unsprayed plots of cowpea-maize plots were subjected to ANOVA using Randomized Complete Block Design (RCBD). Regression analysis of maize grain yield obtained from the early maize of maize-maize plots verse N-fertilizer levels in 2006 and 2007 were used to determine the fertilizer equivalent of the preceding cowpea plots (Sarrantonio, 1991).

RESULTS AND DISCUSSION

The three years average of biomass and grain yields of cowpea and maize plants are presented in Table 1. Cowpea biomass in the late season of 2004 was consistently and significantly higher than those of 2005 and 2006 in 4, 8 and 10 WAP whereas cowpea plant biomass in 2006 cropping season was only significantly higher than that of 2005 at 8 WAP. Cowpea plant in 2004 had the highest grain yield while that of 2005 had the lowest. These different performances in biomass and grain yield of cowpea observed between 2004 and 2005 late cropping season were not unconnected with the effects of both land use intensification and early cessation of rainfall in 2005 whereas the differences observed in 2006 could be attributed to land use intensification.

Maize plants in 2005 and 2006 early cropping season had similar biomass but were significantly higher than those of 2007. However, the maize grain yield obtained from each cropping season decreases significantly as the cropping season advances. This is an indication that cowpea-maize sequential cropping could neither be stabilized nor sustained for long time unless supplemented with minimal inorganic N-fertilizer in addition to the P-fertilizer.

Cowpea biomass obtained from the sprayed and unsprayed plots of late season at 4 and 6 WAP were similar because spraying of insecticide commenced at 6 WAP. However, the sprayed cowpea had higher biomass and grain yield than the unsprayed cowpea at 8 and 10 WAP due to the formation of pods as a result of insecticidal spray which protected the pods. The year by insecticidal spray interaction was significant suggesting that insecticide sprayed at 8 and 10 WAP on cowpea plant responded to insecticide application differently in the three late cropping seasons (Tables 2

Table 1. Effects of season and insecticidal spray on biomass and grain yield of preceding *cowpea and maize

Treatments	Biomass (g/plant) of cowpea at				Cowpea grain yield	Biomass (g/plant) of maize at				Maize grain yield
	4 WAP	6 WAP	8 WAP	10 WAP	$t \cdot ha^{-1}$	4 WAP	6 WAP	8 WAP	10 WAP	$t \cdot ha^{-1}$
Year (Y)										
2004/2005	3.92	16.12	73.0	97.79	0.67	15.95	51.08	83.46	140.17	2.90a
2005/2006	2.43	8.70	18.85	26.85	0.32	14.48	42.98	89.07	129.99	1.28b
2006/2007	2.76	11.53	30.33	43.70	0.42	5.23	26.36	41.37	67.96	1.00c
Mean	3.04	12.37	40.73	56.11	0.50	11.89	40.14	71.30	112.71	1.82
LSD (Y)	0.83	5.27	5.19	13.19	0.022	1.98	10.90	30.29	21.63	0.193
Spray regime (S)										
No spray	3.01	12.26	35.37	45.79	0.19	11.61	40.19	69.5	111.26	1.68a
Spray	3.07	12.03	45.70	66.43	0.83	12.17	40.09	73.07	114.15	1.78a
Mean	3.04	12.15	40.73	56.11	0.51	11.89	40.14	71.29	112.71	1.73
LSD (S)	NS	NS	4.85	4.57	0.04	NS	NS	NS	NS	NS
LSD (Y x S)	NS	NS	S	S	NS	NS	NS	NS	NS	NS
Variety (V) + maize										
IT90K-76-maize	2.83a	13.39a	43.67a	58.47a	1.11a	13.00a	44.68a	73.29a	120.77a	1.98a
IT90K-277-2-maize	3.08a	13.39a	39.86a	57.76a	0.80b	11.03a	38.17a	70.40a	108.93a	1.56a
Drum-maize	2.73a	10.66a	39.80a	49.79b	0.08e	13.16a	39.66a	76.61a	109.56a	1.93a
Olo-maize	3.41a	12.02a	39.76a	44.49b	0.44d	13.37a	38.96a	69.34a	109.24a	1.76a
Oloyin-maize	2.88a	11.35a	43.70a	59.53a	0.81b	9.98a	38.89a	63.42a	101.49a	1.50a
Mallam-maize	3.25a	11.63a	38.64a	59.44a	0.01e	10.74a	41.21a	68.63a	117.71a	1.67a
Sokoto-maize	3.15a	12.83a	39.66a	63.30a	0.87b	11.88a	39.42a	77.30a	121.26a	1.67a
Mean	3.05	12.18	40.73	56.11	0.59	11.88	40.14	71.28	112.71	1.73
LSD (V)	NS	NS	NS	9.60	0.075	NS	NS	NS	NS	0.250
LSD (Y x V)	NS	NS	NS	S	NS	NS	NS	NS	NS	NS
LSD (S x V)	NS	NS	NS	NS	S	NS	NS	NS	NS	NS

Interaction Y × S × V was not significant, NS = $p > 0.05$ and S = $p < 0.05$.
* Modified from Adigbo and Adigbo, 2011

and 3). There was appreciable difference between the cowpea plant biomass in both 8 and 10 WAP of 2004 cropping season whereas the difference observed in 2005 and 2006 were negligible.

The succeeding maize had similar biomass and grain yield irrespective of the insecticidal treatment of the preceding cowpea plot (Table 1). This implies that spraying preceding cowpea to increase cowpea grain yield had similar effect on the succeeding maize crop compared to the unsprayed cowpea.

The preceding cowpea varieties had similar biomass at 4, 6, and 8 WAP. However, at 10 WAP when pod formation and grain filling set in, there were significant differences among the varieties. *Sokoto*, IT90k-76, IT90K-277-2, *Oloyin* and *malla*m varieties had similar biomass but were significantly higher than those of *Olo* and *Drum*, suggesting that photosynthate accumulation was lower in *Olo* and *Drum 10 WAP*. The photosynthate partitioning to the harvestable part (grain yields) of cowpea varieties were significantly different from each other. The final grain yield obtained suggests IT90K-76 had the highest ability to partition photosynthate to harvestable compared to the others whereas *Mallam* and *Drum* were the lowest. The grain yield of the two local varieties (*Sokoto* and *Oloyin*) and one of the improved varieties (IT90K-277-2) were similar. This appeared to contradict the findings of Singh et al. (1997) who reported that improved varieties usually gave higher grain than the local varieties.

The preceding cowpea varieties did not influence the

Table 2. Year by insecticidal interaction on biomass of cowpea at 8 WAP

Year	Unsprayed	Sprayed
2004	59.99	8701
2005	18.13	19.57
2006	30.13	30.52
LSD (P = 0.002)	9.00	

Table 3. Year by insecticidal interaction on biomass of cowpea at 10 WAP

Year	Unsprayed	Sprayed
2004	74.48	121.09
2005	25.26	28.44
2006	37.62	49.77
LSD (P = 0002)	8.488	

Table 4. Grain yield of maize as influence by ǂ cowpea-maize and maize-maize sequence

Treatment	Grain yield of preceding cowpea (t·ha^{-1}) Aug –Nov				Grain yield of succeeding maize (t·ha^{-1}) April – July			Cowpea fertilizer equivalent	Cowpea fertilizer equivalent
	2004	**2005**	**2006**	**Mean**	**2005**	**2006**	**2007**	**2006**	**2007**
Crop sequences									
IT90K-76-maize	1.49	0.88	0.99	1.19	3.18a	1.39ab	1.30abc	37	26
IT90K-277-2-maize	1.10	0.62	0.85	0.86	2.66a	1.28abc	0.75cde	30	10
Drum-maize	0.10	0.00	0.11	0.05	3.17a	1.38ab	1.25cde	38	23
Olo-maize	1.01	0.36	0.68	0.69	2.79a	1.37abc	1.31abc	37	27
Oloyin-maize	0.96	0.77	0.96	0.87	2.74a	1.16bc	0.61de	24	06
Mallam-maize	0.05	0.00	0.10	0.03	2.94a	1.23abc	0.84cde	28	12
Sokoto-maize	1.39	0.50	0.86	0.95	2.70a	1.14bc	1.27abcd	23	24
Mean of cowpea -maize					**2.88**	**1.28**	**1.05**	**31**	**18**
Maize-maize (0 N kg/ha)	-	-		-	1.96a	0.65c	0.37e	-	-
Maize-maize (30 N kg/ha)	-	-		-	2.68a	1.20abc	0.94bcd	-	-
Maize-maize (60 N kg/ha)	-	-		-	2.81a	1.67a	1.62b	-	-
Maize-maize (90 N kg/ha)	-	-		-	2.89a	1.65a	1.78a	-	-
Mean of maize-maize					**2.59**	**1.29**	**1.18**		
LSD	0.03**	0.04**	0.04**	0.032**		1.32	0.49*	0.53**	

-Data were not collected
ǂ Modified from Adigbo and Adigbo, 2011

biomass and grain yield of the succeeding maize (Table 1). This suggests that fodder cowpea *Drum* and *Mallam* which had zero N-harvest indexes (where no product is harvested) and grain cowpea varieties had similar effects on the succeeding maize. This result contradicted the opinion of Giller et al. (1994); Adigbo and Momoh (2007) who reported that the only way to have large input from N-contribution to the succeeding crop is to use a green manure legume, which has a zero N-harvest index. Giller et al. (1994) reported that for agricultural system to be sustainable in the long term, the resource base must be guaranteed and if legumes are not to drain N from the system, they must fix at least much N as is removed from the field in grain and other produce when the legume is harvested. It therefore implies that IT90K-76, *Oloyin*, *Olo*, IT90K-277-2 and *Sokoto* which gave harvestable yield (grains) probably contributed more nitrogen via biological N-fixation than the *Drum* and *Mallam* which had zero N-harvest indexes.

It is important to note the general reduction in grain yield of cowpea in 2005 compared to the other cropping seasons (Table 4) was due to early cessation of rains. The responses of IT90K-76, IT90K-277-2 and *Oloyin* varieties of cowpea indicated their ability to endure drought and reduce risk during adverse weather conditions.

The pooled means of maize grains from sprayed and unsprayed preceding cowpea-maize sequential plots and those of maize grains from maize-maize were similar in 2005 cropping season (Table 4). However, the maize grains obtained from IT90K-76-maize, IT90K-277-2-maize, *Olo*-maize, *Mallam*-maize, *Drum*-maize sequences were comparable to those of maize-maize that received 30, 60 and 90 kg N ha^{-1} in 2006 cropping season. In 2007 cropping season, only IT90K-76-maize, *Olo*-maize and *Sokoto*-maize compared favourably with those of maize-maize that received 90 kg N ha^{-1}. The similarity between the maize-cowpea sequences and those plots of maize-maize which received 90 kg N ha^{-1} could be attributed to the fact that cowpea residue has additional beneficial effects on the soils' chemical and physical properties (Bationo and Mokwunye, 1991). These includes potassium (Allison, 1990), organic matter and micro nutrients in balance form compared to the plots that received only N-fertilizer in an unbalanced form.

The estimated fertilizer equivalent of the preceding cowpea ranged between 23 and 38 kg N ha^{-1} in 2006 cropping season while that of 2007 was between 06 and 27 kg N ha^{-1} according to Sarrantonio (1991) method. The fertilizer replacement value obtained from this study had similar value to what was obtained in green manure using *Mucuna utilis* in Adigbo et al. (2003) who reported 30 kg N ha^{-1}. It is pertinent to note that nitrogen fertilizer replacement value was decreasing as the cropping seasons advance. Swink et al. (2007) who reviewed fertilizer replacement of preceding soybean on corn gave a similar report. For this systems to be sustainable therefore there is need for minimal inorganic fertilizer to supplement the contribution of cowpea.

In general, the average maize grain yields obtained from cowpea-maize sequences were similar to those of fertilizer plot of maize-maize cropping sequences suggesting that

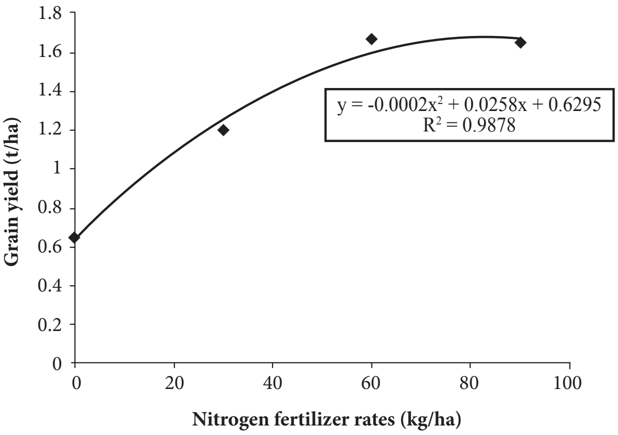

Fig. 1a. Regression analysis of N-fertilizer on grain yield of maize in 2006

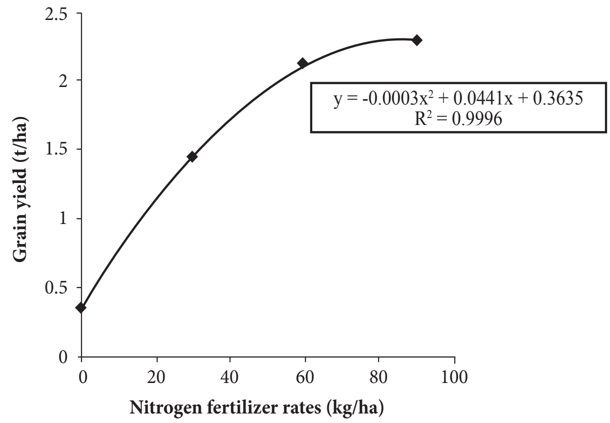

Fig. 1b. Regression analysis of N-fertilizer on grain yield of maize in 2007

Fig. 1. Regression analysis of N-fertilizer on grain yield of maize in 2006 and 2007 cropping seasons

cowpea-maize (gave both cowpea and maize grains) is not only more beneficial but more productive compared to green manure with non-harvestable product and fertilizer treated plots that may likely pollute the environment apart from it prohibiting price.

Regression analysis shows that relationship between grain yield and applied N was curvilinear in 2006 and 2007 cropping seasons (Fig. 1). The coefficient of determination (r^2) of 0.9878 and 0.9996 accounted for 98.78% and 99.96% variability of grain yield in 2006 and 2007, respectively. The model parameter ($y = a + bx$) from the two equations showed that interception in 2006 cropping was 1.75 times greater than that of 2007, thus indicating that fertility status was declining.

Based on the study, spray or no spray of insecticide on the preceding cowpea had similar effect on the performance of succeeding maize. It also showed that IT90K-76, *Oloyin*, IT90K-277-2, *Sokoto* and *Olo* varieties produced appreciable harvestable grain yield as well as contributed N to the succeeding maize. The estimated fertilizer equivalent value of the preceding cowpea to the maize grain yield ranged between 23 and 38 in 2006 cropping season while it was 06 and 26 in 2007.

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